The Foundry Trade Journal

AND PATTERN MAKER.

THE OFFICIAL ORGAN OF THE INSTITUTION OF BRITISH FOUNDRYMEN.

Vol. 22. MAY, 1920. No. 221.

Rotary Casting Machines.

By G. Williams.

By rotary casting machines is meant those in which casting is assisted by centrifugal force. There are two main classes, those in which centrifugal force is made use of horizontally, and those in which the force is made use of vertically. The two can be simply illustrated. If a volume of liquid be placed in a cup-shaped receptacle, and the whole be revolved, the liquid will tend to press outwards against the sides and leave the middle. The surface of the liquid takes a curved form. If, on the other hand, the liquid be placed in a drum-like container, whose axis is horizontal, and the whole be revolved on this axis, the liquid will spread itself evenly over the inside of the drum and leave a cylindrical hollow in the middle.

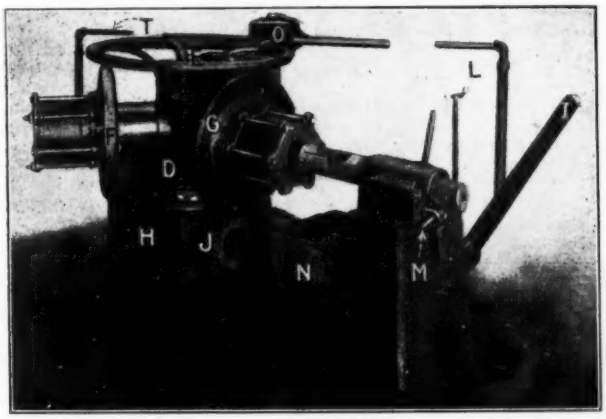

FIG. 1.

A machine designed by J. Whitley in 1865 is an example of the first class of machine. It consisted of a mould lined with a mixture of silicate and plumbago, revolved around a vertical axis, and was used for casting tyres for railway wheels. The casting in this instance was allowed to remain in the mould in order to cool slowly. In effect this machine consisted of very little more than the making of an ordinary mould and revolving it during casting.

An illustration of the second class of machine occurs in a Patent Specification by W. Thompson in 1873, for the purpose of casting lead sheets. Molten lead was poured into a cylinder revolving on rollers, and having flanges at the ends projecting inwards. The metal was spread evenly over the surface of the cylinder by the action of centrifugal force, and when set the sheet was cut longitudinally with a knife and removed through the end. The moulds in this case were made of metal, and the process was, in fact, an example of permanent mould casting.

As to the development of rotary casting machines, the first attempt, apparently, dates back as far as 1809, 111 years ago. The most instructive survey, however, can be obtained from a series of patents taken out by two gentlemen of the names of Samp-son Fox and Joseph Whitley over a period of years from 1879 to about 1885. In one of the first patents taken out by the two inventors the cylindrical horizontal permanent mould is apparent, as usual, but the runner or pourer has received special attention. It consists of a bottom pouring ladle, mounted on wheels, with a trough or pipe perforated with a number of holes along the bottom extending into the mould to carry the flow of metal. Evidently the pourer was designed in this way to ensure that the mould received the metal from end to end for the prevention of cold laps, uneven thickness in the casting, and suchlike troubles. It may be mentioned that this machine was designed for the casting of steel and other plates for boiler making, shipbuilding, and other purposes, such as tubes for internal fire boxes and flues.

The next step in the history of the process is seen

* Read before the Coventry Branch of the Institution of British Foundrymen, January 23, 1920—Mr. A. Harley in the chair.

in another patent taken out by the same gentlemen in 1884. In this it is stated that a reciprocating motion is given to the fluid metal when flowing into the moulds, and also the introduction of compressed air into the interior is claimed. It is evident that this Specification, like the last, pays attention principally to the way in which the metal is caused to flow into the moulds. In the language of the patentees, "the vacuum caused by the great heat

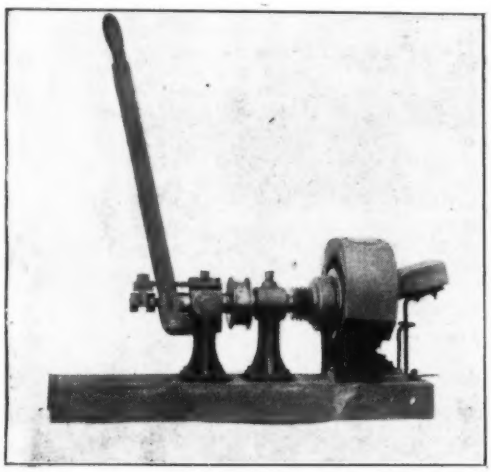

FIG. 2.

in the respective moulds causes a tendency to create not only drawn but blown holes." The idea of introducing compressed air was obviously to neutralise the vacuum they speak of. They gave a reciprocating motion to the metal, so that—to quote the patentees again—"plates, shells or sheets so made will be perfectly free from chill or wave lines, seeing that the metal is not suffered to fall on the same spot, but receives whilst in its fluid state a motion like unto the webs of woven fabrics when passing over a folding or measuring machine, thereby interlocking, as it were, the whole of the molecular of the entire mass, whatever its thickness may be, and thus preventing the formation of those common centres of heat, the tendencies of which are to form partial porosity by feeding the consolidating or the crystallising of the total mass contained in castings so constructed."

This eloquence is certainly a tribute to the imagination of these gentlemen.

The next step is a patent taken out by Mr. J. Whitley, alone this time, and is perhaps a retrogressive rather than a progressive one. He proposes in this to use moulds lined with asbestos, talc, or other heat-resisting packing as differentiated from casting directly in a chill mould. The reason given for lining the mould with refractory material is that by this means the heat force in the liquid is materially reserved from external radiation and transmission, thereby creating a greater density and homogeneity in the molecules, and obtaining a greater tensile strength. It is evident that the last three Specifications form a history of troubles experienced, and an attempt at their solution. They do not show, however, a correct appreciation of the source of the trouble, although the last Specification by J. Whitley gives the remedy. This matter is dealt with below.

To go back again a little way, two other ideas appearing among these two inventors' patents deserve mention. One is an attempt at weighing the metal before pouring it into the mould as a remedy for varying thicknesses of successive castings, and the other the mounting of the mould in a shell and the ejecting of the whole after casting by means of a screw and handwheel.

Outside these very interesting Specifications there are various isolated instances of the application of centrifugal force in other directions, one being described in a patent taken out by Sir Hiram Stevens Maxim and Hudson Maxim in 1895. This invention purported to make pipes in continuous lengths by the rotary process. The method proposed was to feed the metal into one end of a rotating mould which was tapered towards the feeding end, so that the liquid metal as it was introduced pushed out the partly solidified metal in front of it. The further end of the mould was kept cold by means of a water jacket, and the solidified pipe was helped to issue out of this end by means of tangential rollers. There is also mentioned in this patent a means for introducing into the interior of the mould a neutral or reducing gas for preventing oxidation. The introduction of such a gas is significant, as will be seen later.

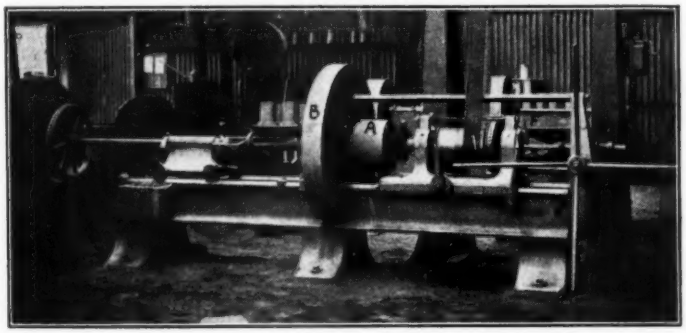

FIG. 3.

Another patent taken out in 1917 relates to the making of wheels whose tyres are of a different

material from the body. For instance, in the case of railway or tram wheels the tyres can be made of manganese steel and the body or hub of the usual mild steel.

A rotary casting machine which is at present being worked in the United States is seen in Fig. 1. It is used for the purpose of casting piston rings as individual castings, a number at a time. The machine consists of a standard to which four moulds can be attached, and round which they move, so that each in succession comes opposite to the pourer. The moulds are made up of a series of discs or plates clamped together so that the spaces in between form the moulds for the piston rings. After casting, the whole mould is transferred to a machine which dissembles it and removes the rings. The action is continuous, for no sooner is a cast mould removed than another already assembled takes its place ready for casting. The rings which are produced are, of course, chilled, in spite of a high percentage of silicon, because the size of the casting is so small in comparison with the size of the mould, and they have to be annealed in furnaces of a continuous type in which they are fed at the top and emerge from the bottom.

The rotary casting machines used at the British Piston Ring Company, Limited, for casting piston

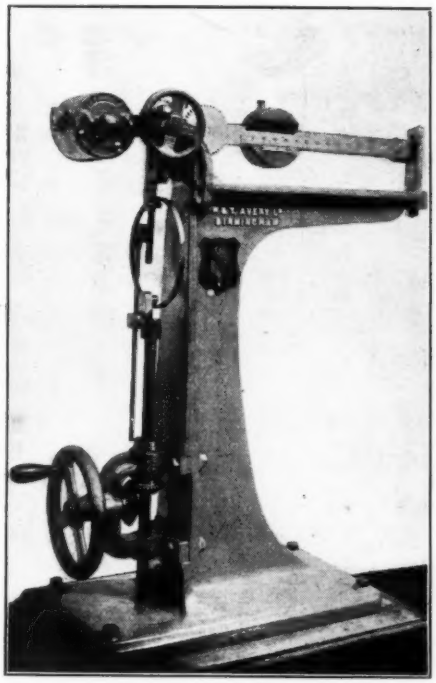

FIG. 4.

ring pots were patented by Mr. Oubridge, of the above firm, and another machine for casting fuses, pistons, and other small articles of irregular shape, was patented by Mr. Oubridge, another gentleman and the author. The design of both machines centres entirely round the rapid stripping of the mould from the casting when it is made. In the piston ring pot machine (Fig. 3), for instance, the end plate is not bolted on to the mould in any way, but is held by an independent bearing, or its mechanical equivalent, tight up to the body of the mould. A plunger operates on the other end of the casting when it is made, allowing only of a slight movement for clearance, so that when the rack and pinion comes into operation, drawing back the mould, the casting literally falls out. In the other machine the moulds or discs are arranged

FIG. 5.

round a central chamber, from which the metal flows into them by short runners. The moulds are split vertically, one half being held by an independent bearing, and the other half attached in series, so to speak, with the rack and pinion, for easy stripping. The plunger is again apparent, and a device operates also for the removal of cores by centrifugal force.

Another firm employing rotary casting machines successfully in this country is Messrs. Stokes Castings, Limited, Mansfield, the machines which they use being patented by Mr. F. W. Stokes.

The first experiments which were made at the British Piston Ring Company, Limited, consisted of the stationary casting of single rings on a small machine, one at a time. This was not a rotary machine, and the core, as well as the mould, were made of iron. It was this little machine that taught the experimenters the importance of the rapid removal of the casting, for every one of the rings made before adopting a means for opening the mould quickly was split and broken. To get a complete ring, the machine had to be opened in less than two seconds after casting, before the caster hardly had time to move away. The second little machine was a rotary one, and the same means for rapid ejection were incorporated in it (Fig. 2). After that the casting of pots was but a short step to take, since a piston ring pot is nothing more than a very long or wide ring.

The actual operation of casting on the machine may be described with the aid of Fig. 3. First the mould inside the shell A is brought up tightly against the end plate held by the independent bearing (hidden in the figure behind the guard B) by means of the capstan handles C. The mould is then rotated. Molten metal is brought to the ladle D, the spout of which is pushed into the mould through the end bearing, and by tilting the handwheel E the metal flows into the mould. In a few moments the casting is set. The rotation of the mould is stopped, and the handles C are operated to strip the mould from the casting. The plunger, which is situated at the front end of the rod F, remains nearly stationary, and serves to eject the casting in its red-hot state. The opera-

tion takes far longer to describe than to perform. In practice very few moments serve to convert molten metal into finished castings.

There is no necessity to weigh, or otherwise measure, the amount of metal that is put in the ladle. All that is done is to make the hole in the end plate of the same size as the required bore of the finished casting, and allow any excess metal to overflow into the guard. If a little care is taken

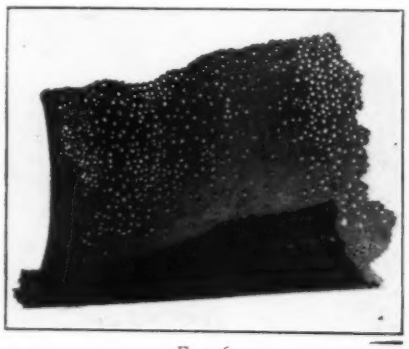

FIG. 6.

to see that no excessive variations of temperature occurs on successive ladles-ful of metal, no variation will be found in the thickness of the castings. Of course, it is possible to have short runs, but if the caster watches the sparks he cannot help knowing when the overflowing of the metal takes place.

Piston Ring Cast Iron.

Before describing the difficulties and limitations of the rotary casting method, it is necessary to consider what is meant by piston-ring iron. As is well known, the iron from which piston rings are made has to be of special quality, both as regards tensile strength and elasticity, that is, non-liability to permanent set. It must be close grained, and hard enough to resist the considerable wear a piston ring is subjected to. These qualities can only be attained when the iron contains about 0.8 per cent. combined carbon, that is, when it is as near as possible to being chilled without actually going over the line. The 2K6 Specification of the Aircraft Sub-Committee W. of the British Engineering Standards Association was drawn up with this underlying idea.

In the same Specification is included a tensile test for actual rings that the author originated. The ring it is desired to test is measured up, split or fractured, and then broken by being pulled apart on a small tensile testing machine (Fig. 4). Then from the poundage at which the ring breaks the tensile strength of the material in tons per square inch can be calculated by a formula. This method is useful, since it does away with the necessity for relying on test bars which may or may not represent the castings which they are intended as tests for, and allows any ring to be picked up in the machine shop and tested immediately. Any casting which admits of a ring being machined from it, for instance, a piston casting, can be tested in the same way.

It should be mentioned that Capt. Smith-Clarke, late of the A.I.D. (Coventry District Engines), carried out a long series of tests in this way, and it was his results and the interest he took in the matter which served to justify this method of testing being incorporated in the Aircraft Specification.

A further test for permanent set, or "elasticity," is being considered by the above Aircraft Sub-Committee. This is apparently the first time that this property of cast iron has been commercially tested; in fact, there are very few classes of work in cast iron where this property needs testing. To produce iron rigorously to Specification to pass these severe tests is the crux of the whole piston-ring material problem.

It is necessary then that any rotary casting method to be applicable to the making of piston ring pots must be susceptible to considerable control as regards the properties of the casting, or, in other words, the controlling of the combined carbon must be fairly easy. Experience shows that this essential is attained when the moulds are worked *as hot as possible*. Of course, the castings must be ejected from the machine with mathematical regularity, immediately they are set.

Other users of the rotary method usually work the moulds from the opposite point of view, as cold as possible.

For instance, in the "Founders' Manual" is given a record of permanent mould casting carried out by Mr. Edgar A. Custer, in the United States, as follows: "Without giving definite information as to sizes of moulds in relation to sizes of castings, Mr. Custer impressed the necessity for great mass in them. For instance, a mould for a 2 in. soil pipe T weighs 500 lbs., one for a 3 in. trap 1,700 lbs., and in a mould for a 4 in. soil pipe weighing 65 lbs. there were 6,500 lbs. of iron. Castings were made in this mould every seven minutes, without raising the temperature over 300 degrees Fah. Mr. Custer states that the moulds improve by continual use, and at the time

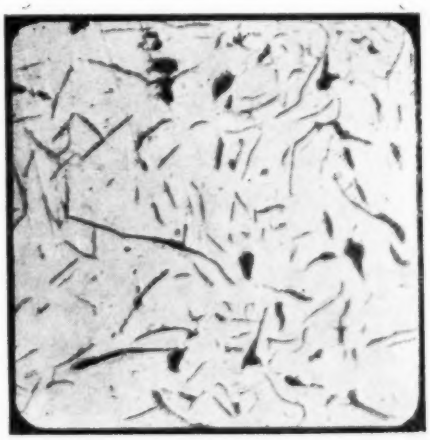

FIG. 7.

of giving his paper before the American Foundrymen's Association he had one in which 6,000 castings had been made. He also emphasises the necessity for removing the castings immediately they are set.

The moulds used at the British Piston Ring Company, Limited, in comparison with Mr. Custer's, are very flimsy things, for the thickest at present on the machine is 1¼ins. The moulds in

the first experiments were little more than ½ in. thick, the reason being that it was desired to cast with the moulds as hot as possible.

The laws which connect silicon percentage, rate of cooling and combined carbon, operate in the case of permanent mould casting as in the case of sand casting. That is to say, whether casting in sand or in a permanent mould, the quicker the rate of cooling, other things being equal, the higher must be the percentage of silicon in the metal to product a given percentage of combined carbon. Thus, generally speaking, since permanent moulds cause a more rapid cooling than sand, the silicon percentage in the metal cast in the chill mould must be higher than in the case of sand to obtain the same result. Sometimes the rate of cooling of the permanent mould is so great that the castings will persist in being chilled, in spite of a high percentage of silicon. This is the case with the American machine for casting individual piston rings, for the softening influence of silicon ceases at about 4 per cent.

One of the troubles of casting in cold moulds is the chilling of ends or parts of the casting which are subject to the most rapid radiation of heat. The remedy consists of designing the mould in such a way that at the particular points where chill is liable the heat is most conserved. This can be done by making that part of the mould thin, or by covering it with layers of non-conducting material. One of the reasons why the moulds in the machine illustrated are attached to their shell by means of a flange round their middle is that by so doing the heat is more conserved on the ends; or, to put it the other way about, the part of the mould which is most liable to overheating is the middle, so to equalise matters the moulds are attached to their shell by their middle.

The life of the moulds in comparison with Mr. Custer's large output per mould is very short.

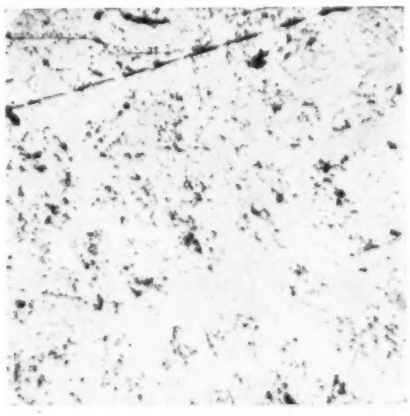

Fig. 8.

This is because of the drastic treatment they receive. The author is generally content if 300 castings per mould are obtained, for even with this quantity the cost of the mould spread over the castings obtained from it is a very small item.

The reason for the deterioration of the moulds is annealing and penetrative oxidisation due to repeated heating and cooling. This annealing is accompanied by growth. The matter is not serious, however, provided all parts of the mould receive the same treatment. If, for instance, the back end of the mould is persistently hotter than the front end, trouble will eventually ensue with regard to getting the castings out of the mould, for the rear end of the casting will be larger than the aperture through which it has to be ejected. This forms another reason why the moulds are attached to their shell by their middle in the above machine.

Fig. 9.

The bugbear of casting in hot moulds is pinholes (Fig. 5). They take the form of little cavities in the casting caused by gases trapped in trying to find an escape through the molten metal when it is poured. The author has found that there are apparently two sources of these gases, one source being the air that is trapped in the interstices of the inside surfaces of the mould, and the other source being a chemical one, namely, the decomposition of the oxides lining the interior of the mould. The trapping of the gases in the minute depressions of the surface of the mould can be overcome by paying attention to the method of pouring. The iron must be run in such a way that this air is swept before the metal from one end of the mould to the other. The way the author found the best method of pouring was in casting aluminium pots, which metal does not cause the chemical decomposition of the oxides lining the interior of the mould.

The other source of trapped gases comes into play when casting iron. The carbon in the iron, when it comes into contact with the oxides lining the mould, decomposes them with the formation of carbon monoxide and dioxide in proportions according to the temperature. That this actually happens was borne upon the author from observation of specimens under the microscope, which showed apparent decarburisation at the edges of the pinholes. The main body of the casting was made up of a pearlitic matrix, whereas tracts of ferrite could be seen round the holes. Further, to test this theory, an experiment was carried out to determine what would happen when the iron came in contact with an oxide artificially introduced into the mould. First, all traces of plumbago were removed from the mould, and red lead, being an oxide easily reducible by carbon, was introduced. Molten metal was poured into the machine, and the result was a stuck casting. Persuasion failed entirely to eject the casting, so it had to be turned out in a lathe. Part of the shell that remained is shown in Fig. 6, which also shows that the theory was upheld. Subsequent examination of the inside surface of the mould showed also small bright globules which were evidently metallic lead,

reduced from the oxide. No doubt these were the cause of the sticking.

The second source of pinholes being now fairly well established, it remains to consider the remedy. Obviously, if the carbon in the molten iron could be prevented from coming into intimate contact with the oxidised surface of the mould, or, on the other hand, the surface of the mould could be prevented from becoming oxidised, the remedy was found.

Consequently, with the latter idea in mind, moulds made of materials less liable to oxidisation than cast iron were tried. Two or three such moulds were made of "Reactol" steel—as the product is called—a material which is used with success for hardening boxes, due to its resistance to oxidation. The use of this material for the moulds certainly did reduce the scrap caused by pinholes by more than half, but, unfortunately, the gain was not proportionate to the cost. The conclusion arrived at, after experiments in several directions, was that the solution of the problem by finding a non-oxidising mould material was impracticable. It may be possible in laboratory experiments to have moulds made of nickel, or other still more expensive metals which do not oxidise easily, and obtain success with them, but many practical difficulties arise which put entirely out of court the working of such moulds commercially.

In Sir Hiram Maxim's specification is mentioned the introduction of neutral or reducing gases into the mould for preventing oxidisation. The idea is feasible with such a continuous mould as his was, but where the mould has to be continually opened in order to eject the casting, it is difficult to see how the oxygen of the air can be prevented from getting to the mould without enclosing the whole machine in a lethal chamber!

The alternative is to prevent the molten iron from coming in contact with the oxides of the mould, by having the mould lined with some thin coating of refractory material, as suggested by J. Whitley in one of his later Specifications. Such a lining might take the form of a thin coating of loam, or thin fireclay shells could be used, being placed in the mould just previous to casting, and ejected with the casting. Very thin sheets or shells of steel might answer the same purpose. Messrs. Ford in America produce a large quantity of piston ring pots by the rotary method, and it is believed that it is their intention to try carbon shells. The author simply used plumbago of good quality for the purpose, care being taken that the plumbago is distributed as evenly as possible over the entire surface of the mould. Plumbago, however, is not a certain remedy for the trouble.

There is, of course, a critical temperature, below which the dissociation of the iron oxide does not occur, and if the character of the work is such that the temperature of the mould can be kept below this point, the pinholes will not appear. Such is the case with Mr. Custer and with the American machine for producing piston rings individually. In the latter case the castings are chilled, so that it matters not how cold the moulds are kept.

Superiority of Rotary Castings.

Not only do rotary castings as a whole show superiority over sand castings on production, but they are also superior in physical properties. If the distribution of the graphite in rotary castings be examined under the microscope (Figs. 7 and 8), it will be seen that the large flakes usually seen in sand castings are absent, the graphite in the rotary casting being more in the form of nodules resembling the temper carbon in malleable castings. This distribution of graphite materially helps in giving to the iron a good tensile strength as well as a good "elasticity." Since also the size of the graphite particles determines to a great extent the closeness of grain when viewed by the eye, rotary castings are much superior in this respect (Fig. 9).

The cause of the closeness of grain and the small size of the graphite particles is, in the author's opinion, nothing more than rapid cooling. The effect of the centrifugal method, or the pressure due to it, is negligible. In corroboration of this the following may be adduced.

The pressure of the molten iron against the surface of the mould can be determined by the following formula:—

If F = centrifugal pressure on mould in lbs. per sq. in.,
N = revolutions of mould per minute,
D = diameter of casting in inches,
t = thickness of casting in inches,

then

$$F = .000045tDN^2.$$

It can be seen from the formula that the pressure is proportional to the thickness of the layer of molten metal that is going to make the casting. That is to say, the layer that is most subjected to pressure is that next to the mould, and the layer that is least subjected to pressure that on the extreme inside. Assuming the mould to be revolved at a speed giving a pressure of 60 lbs. on the surface of the mould, the pressure half-way through the layer of molten metal will be 151 lbs., and on the extreme inside layer of molten metal the pressure will be nothing. Hence, if pressure had anything to do with the closeness of grain, it would be expected that the layers of the casting next the mould would be much closer than those farthest from the mould. This is not so, for no difference can be observed with the highest powers of the microscope between the inside and outside of a piston-ring pot casting. Moreover, it is possible artificially to produce a casting that is more open-grained at that part which is subjected to most pressure, and closer grained at that part which is subjected to least pressure. This can be done by rapidly cooling the interior of the molten metal by a stream of compressed air. It follows that the rate of cooling of the casting has far greater influence on closeness of grain than pressure has.

The advantage of closeness of grain, and tensile strength and elasticity that usually go with closeness of grain, therefore is not confined to rotary casting, but should be a feature of all permanent-mould casting. Where rotary casting, however, scores over ordinary permanent-mould casting is that the speed of production is greater, the moulds can be made comparatively simply, and there is no trouble with complicated gates and runners.

With the rotary method, dirty castings are entirely eliminated. This is due to the centrifugal action having a tendency to throw all the lighter constituents to the inside, so that all slag and rubbish which may be present in the metal is flushed out, and overflows into the guard of the machine. The only cause of scrap that is excusable in rotary casting is the pinholes due to the decom-

position of the oxides of the mould. There is no reason whatsoever when casting non-ferrous metals that a single scrap casting should be made.

There is no need to dwell on the exact significance of these benefits, they are apparent to all readers. Processes such as the rotary method, mechanical processes designed to eliminate as far as possible human element and uncertainty, are the one and only road to the scientific production of castings, and there is no doubt that when the future of such processes is fully worked out they will attain a prominence that will entirely eclipse the venerable antiquity of sand casting.

Discussion.

THE CHAIRMAN (Mr. A. Harley) said that this was one of the latest developments in regard to foundry practice. They were greatly indebted to Mr. Williams and also to the British Piston Ring Company for permission to show all the data and the results of the rotary process.

Replying to Mr. Mallabone, who wished to know the percentage of defective castings, the author said that that was rather a difficult question to answer from memory, because of the distinction between defective castings of complete pots and defective piston rings machined from such pots. With regard to the latter, during the war the percentage of defective rings from sand castings amounted to as much as 40 per cent. With rotary castings the scrap percentages do not exceed from 15 to 20 per cent. No doubt under the best conditions and with increasing experience the percentage would be considerably decreased.

A MEMBER inquired as to the best methods of stopping the blow holes in permanent castings. He understood Mr. Williams to mention a special preparation of plumbago. How was it mixed, and what ingredients were used.

MR. WILLIAMS said he had tried many things, including oil, sugar and treacle.

MR. G. E. ROBERTS inquired whether it was possible to adapt the rotary casting machine to the production of regular spherical shapes. He understood that experiments had been conducted on the Continent with a view to producing metal castings of such shapes, and that the machine used had more than one action.

MR. WILLIAMS, replying, expressed his regret that he had no knowledge of rotary casting machines with more than one motion. It might be observed that the American machine illustrated had two motions, one of which came into effect *after* casting. He doubted, however, the practicability of machines with two motions both actually occurring *during* the act of casting.

MR. OUBRIDGE said that while in America a short time ago, as he was particularly interested in rotary castings, he was more than surprised to discover that more than half Ford's output of piston rings was made with rotary casting machines. The machines were so arranged that the mould was removed with the casting, both being allowed to cool together. He (the speaker) pointed out to Ford's people that that involved annealing, and they agreed. He could not, however, imagine good rings being made when annealing took place. He understood the machine illustrated was running at the works of the Standard Piston Ring Company, Limited, Jersey, but he was informed that it was at present out of work. In that case again, they were making rings with chilled material which had to be annealed. He did not regard such annealing with favour, for, if it was not stopped at a certain point, to leave, say, 0.3 to 0.4 per cent. of combined carbon, they would get piston rings of very little use from the elasticity point of view. With regard to the reference that had been made to scrap, it was rather difficult, as Mr. Williams said, to give percentages. When they talked of a percentage of 40, it rather looked as if someone was going out of business, but they had had that in their works and were still going along merrily. In fact, with one particular design of ring, produced during the war from sand castings, as much as 80 per cent. of scrap had been obtained; in other words, they had to make 180 for every 100 rings required. It should be said that this figure included the scrap made in the machine shop. It was really absolutely impossible to get a scrap casting from the rotary machine apart from the pinhole trouble, which accounted for the scrap that was made. They could see that the ordinary causes of scrap were absent, for example, there was no source of trouble such as sand. Then all the sulphur and slag was necessarily thrown to the inside of the casting, and if the casting were poured with an excess of metal, none of these would remain in the casting. It was really impossible to get anything like that known in the ordinary sense as a scrap casting.

MR. G. E. ROBERTS asked could the rotary casting method be used for irregular castings? The rotary system looked very nice for pots, but he would like to see it adapted to such articles as the production of hubs, bottom brackets, and crank cases.

THE CHAIRMAN remarked that Mr. Oubridge had guarded himself by saying that they could not make scrap apart from pin holes, but that was a very big qualification, and he (the speaker) quite agreed that nobody would make very much scrap if they could eliminate pin holes. He was quite prepared to believe that there was not one *pot* which was scrapped entirely, although there would be *rings* put aside because they machined badly. A suggestion had been made to the malleable people that silicon could be greatly increased, with the result that the time of annealing could be reduced. He (the speaker) was disposed to warn them in that matter to be careful, because he did not see there was any quick or short road by which they could make first class malleable castings. His own experience had been that anything which seemed to permit of quicker annealing was very apt—to quote an old expression—"to come out in the wash," and they would find that their product was not of the best. Increased silicon might, too, lead to serious trouble with malleable castings which had to be subjected to any temperature, such as cycle hubs, which could easily be made brittle in composition if they were modified in the way suggested, although they might be perfectly malleable before they were subjected to heat.

MR. HURREN remarked that he was disposed to agree with the Chairman in regard to silicon in malleable castings, and he would be very dubious about any experiment combining the rotary casting system for malleable production with increased silicon. He would like to ask Mr. Williams what would be the effect of altering the speed of rotation of the mould. Was there a point at which a reduction of speed would lower the quality of the product? He would like to know also what size of piston pot could be produced, or whether so far they had produced entirely all small sizes? No men-

tion had been made of the limits of accuracy to which castings could be produced.

MR. WILLIAMS, in a further reply, referred to the question of making irregular castings by the rotary process. Such very irregular castings as crank cases, he said, were hardly practicable at the present day. Nobody could say, however, what might be possible in another hundred years or so. Certainly a very complicated machine would be necessary to produce such things. But with regard to reasonably irregular castings—castings such as pistons, fuses or the like—these could be produced by a rotary machine. The speaker proceeded to illustrate this by drawing on the blackboard a machine having several moulds or dies arranged around a central chamber from which the metal could flow into them. In effect, this illustrated arrangement was equivalent to the die casting process for small articles. The difference between this machine and the ordinary die casting was that centrifugal force was used to impart the pressure to the metal, and not compressed air or a plunger, as was usual. All bother with runners and the cutting of gits or sprues was avoided. There was no reason why reasonably irregular castings could not be made in this way, similarly to the sample aluminium piston casting shown.

As to the Chairman's remarks with reference to blowholes, the matter might be made clearer by classifying the trouble usually occurring with sand casting. First, there were two sources of blowholes in said casting, one being gases caught by the molten metal due to insufficient venting of the mould, and the other being gases given off by sulphides or slag occluded in the metal. The only blowholes occurring with rotary casting were those due to the gases which came from the oxidised surface of the mould. There were other difficulties in sand casting. A frequent occurrence was to have a small part of the mould washed away by the force of the entering metal, with a resulting dirty casting. This could not occur with rotary casting. Again, in sand casting the caster might easily allow a particle of slag to enter by way of the runner. This could not happen with rotary casting. Thus were all the various sources of scrap eliminated with this process, with the exception of the one already dealt with.

The speed of rotation of the machine was principally determined by experience. The speed was set at that at which they had found least pinholes appeared. It could vary within wide limits. The machine must be run on the one hand at sufficient speed to develop sufficient centrifugal force to hold the metal up, and, on the other, must not be run so fast as to create so great a pressure on the hot mould as to make it dangerous. Should a mould burst, a very serious accident might result. The size of the machine exhibited on the slides was that capable of turning out castings between 4 in. and 6 in. They had a larger machine for producing castings from 6 in. to 12 in., and a still larger machine in course of construction to produce castings from 12 in. to 30 in.

He (the speaker) could not give exact figures of the accuracy of the castings produced. However, the maximum machining allowance on small castings was 1/10th of an inch on the diameter, and on castings above 20 in. 0.15 in. He had, however, seen castings machined up with only 1/32 machining, the actual machining being far less than the maximum allowance. This was accounted for by the fact that often more than one size of ring came from a particular pot. However, he had not yet had a single complaint from the machine shop of there being too much metal to remove from rotary castings.

PROPOSED TUNNEL IN JAPAN.—It has been decided to cut a submarine tunnel under the Shimonoseki Strait. At present the railway systems in Honshu and Kyushu are connected by ferry boats. The scheme provides for the completion of the work in 1928. Two years will be spent in studying the geological formation of the sea-bed, and in drafting the general plans. Actual work will be commenced in 1921. The total length of the line will be seven miles, of which one mile will be completely under the sea. When completed, a through service between Tokyo and Kagoshima will be possible.

DIFFUSION OF COPPER THROUGH CAST IRON.—In a paper read before the American Foundrymen's Association, H. E. Diller states that in experimenting to ascertain the effect of different oxidising packings on annealing malleable iron a bar was packed in copper-oxide packing and annealed at 1,000 deg. Cent. When the bar was taken from the furnace it was found that the copper oxide had been reduced to metallic copper and melted, and that it had penetrated into the iron. An average sample of the bar showed that the carbon had been reduced from 2.70 to 0.60 per cent., and there was 21.4 per cent. copper. A micrographic study of this phenomenon was presented in the paper. In concluding his remarks the author stated that W. E. Ruder, of the research laboratory of the General Electric Company, Schenectady, N.Y., who made the micrographs for the paper, said in regard to the changed structure of the grey-iron bar, that the only explanation he could give for the peculiar structure and the strict line of demarcation between the copper saturated portions and the centre of the bars free from copper was that the entire material up to the dividing line was in a semi-molten condition, and while in this condition the copper oxide became mixed with it and the oxygen was given up by the copper and united with the graphite. The changing of graphitised carbon to temper carbon was very unusual, and until this experiment he had not thought that this change could be brought about short of actual fusion.

STEELWORKS DEVELOPMENT IN MANCHURIA.—The first smelting furnace at the Anzan Steel Works in South Manchuria began to work in May of this year. The output for the first month was about 100 tons of pig-iron per day, which has since been increased to 160 tons, and it is hoped shortly to attain to about 200 tons per day. The second smelting furnace should be in operation by the end of October, 1919. The site of the works is about two square miles in area, and the plant at present consists of the furnace mentioned, eight heating stoves, granulated slag plant, blowing-engine plant, gas-cleaning plant, boiler plant, power house, ore reservoir, coal-washing plant, coke oven, sulphate of ammonia plant, slag-brick plant, water supply works, and waste-water recovery plant. The work to be carried out in the current year includes the second smelting furnace, gas supply plant, gas plant for steel works, coal storage, coal-tar distilling plant, power-house extension, sulphuric-acid plant, boiler-plant extension, and fire-brick plant. At the end of June 607 Japanese and 743 Chinese were engaged at the works. The first part of the programme will be completed with the erection of the second smelting furnace, which will give, with the one already working, a combined output of about 150,000 tons of pig-iron a year. The original plan was to erect four smelting furnaces before commencing on the steel plant, but, owing to the great drop in the price of pig-iron since the armistice, it has been decided to defer the erection of the second two furnaces and push on with the installation of the steel plant. The aim of the South Manchuria Railway Company, which owns the works, is to make steel plates and rails on a large scale.

Foundry Organisation and Costing.*

By Alexander Hayes.

In discussing the question of foundry organisation one is naturally inclined to adopt a critical attitude. Without wishing to cast undue reflection upon the trade as such, the speaker would like to point out some directions in which considerable improvement could be made in the organisation of many foundries.

Commencing with the position of the manager, it is well to define broadly what his activities should cover. He should first be thoroughly acquainted with the firm's policy in regard to the class of work to be taken, in order that he may organise the shop to best cope with incoming orders. He should have absolute control over the supplies of foundry material, and discretion to reject any unsuitable supplies. He should undertake the distribution of incoming orders through the foundry, and the allocation of work to the different gangs of men or charge hands. He should supervise the recording of stocks and ordering of material, and also the cost-keeping of the work passing through his department. He should also keep closely in touch with the metal melters, to ensure that suitable metals are being produced for the different classes of work. He should personally supervise the handling of all big jobs, and co-operate with the foreman, if he has such under him, in deciding methods of work of all classes.

A word of condemnation might here be given regarding the attitude of many employers towards the foundry manager. Too often there is evinced a stupid desire to keep him in the dark in regard to the general policy of the firm in respect to foundry work, the cost of the department, and many other details which would render his operations more intelligible to him. Attempts are often made to economise on materials, with the result that foundry expenses increase disproportionately.

The manager necessarily must be involved in certain clerical duties; for example, all invoices for foundry materials furnished should be passed to him for approval and record in his stock sheets. All correspondence relating to his work should be sent for his perusal, in order that he may keep himself posted with the probable requirements of customers, their complaints and so forth.

All estimates should be referred to him for inspection and approval. Generally, the manager should have complete control over his department, as if it were a separate works.

In regard to the details of foundry operations, there is often a tendency on the part of the manager to concern himself unduly with these, instead of deputing the responsibility to his foreman or charge hands. If the manager has a foreman under him, the duties of the foreman should be concerned chiefly with the general supervision of the shop, including all details. Under him come the charge hands, supervising and conducting different classes of work.

Great care is required in the selection of charge hands, if success is to be attained, as many excellent moulders are quite useless in charge of other men's labour. The charge hands' qualifications should embody technical skill at the work, organising ability, and a considerable amount of tact, in order to maintain the right working spirit amongst the men.

FORM 1.—MATERIAL STOCK SHEET.

MATERIAL. *Pig-iron No. 3 Cleveland.* MINIMUM STOCK 200 cwts.

Date. 1920	Amount Ordered (cwts.)	Amount Delivered (cwts.)	Cost per Unit (cwts.)	Consumption.				Balance. in hand. Amount.
				Job No.	Amount used	@	Cost charged to job.	
			s. d.			s. d.	s. d.	
Jan 1	Stock	610	8 9	716	30	8 9	262 6	580
,, 2				718	60	8 9	525 0	520
,, 5	200			719	10	8 9	87 6	510
,, 6				721	20	8 9	174 0	490
,, 10		100	9 0					590
,, 13				726	5	8 9	43 9	585

The author's intention at first was to discuss the whole question of foundry organisation, but limitations of time render it desirable to confine attention to what is probably the most serious problem in foundry organisation, namely, the proper recording of the cost of different work.

Before proceeding to discuss that, however, reference might be made to the question of recording stocks and consumption of materials. A simple and effective method of doing this is by the use of stock sheets ruled similarly to Form 1. These, inserted in a loose-leaf binder, allocating one sheet for each variety of material, allow an alphabetical record of orders placed, material delivered and consumed on different jobs. The minimum quantity to be kept in stock should be inserted at the top, and the balance in hand marked in after every item of consumption. This allows the stores man, or whoever is concerned, to see at once when fresh supplies require to be ordered. The method of entering up the Stock Sheet is illustrated. Where the prices of different consignments of the same iron vary, and they are put into the same store and used indiscriminately, they may, if desired, be entered on the same cost sheet, but care should be taken to see that the total recorded as consumed at a given price corresponds with the total received at that price. The author considers it good practice in such cases to

* Abstract of lecture before the London Branch of the Institution of British Foundrymen, March 11, 1920, Mr. F. E. Pitts in the chair.

consume (on the stock sheet) the high-priced material first if prices are falling, and the reverse if they are rising. This keeps the unconsumed balance closer into line with its current market value. This method of stock record obviates periodical formal stocktaking and the consequent interruption of work. The stores man can from time to time check the actual balance of any material with his record, and enter any deficiency as a loss to be charged on to the General Cost Sheet mentioned later. The details of the sheets are posted as explained later, from "Stock Consumption Slips," and the work of posting the stock records can be done at any time. The cost clerk can collect them for a day or any suitable period and deal with them when most convenient.

FORM 2.—CUPOLA TIME SHEET.

Name Date

	Hours.	Rate.	£ s. d.
Preparing bottom and patching lining			
Relining Cupola			
Charging and operating Cupola			
Checked by Charge hand			

Cost Keeping.

Accurate cost keeping is probably the greatest problem which the foundry manager has to face. The general subject of cost keeping has, from time to time, been discussed, and methods therefore described; but most systems which are applied in other industries are either very complicated when applied to the foundry, or require a considerable proportion of the expenditure of labour and material to be averaged over a range of jobs.

A clear distinction should here be made between cost keeping and accounting. The latter is concerned mainly with the total expenditure (including wages, material, establishment charges, etc.) in the production of goods for sale, and the payment for same, and the resulting profit or loss on the entire transactions. Cost keeping, on the other hand, is concerned with a detailed statement of expenditure of labour, material, etc., in each operation of production or for each distinct variety of product.

At the outset it may be stated emphatically that if any foundry manager or proprietor expects to obtain accurate and useful information on production costs without the expenditure of more than a little casual incompetent clerical work, he had better relinquish at the outset any attempt at cost keeping, and be content with his accountants' statement of profit and loss. It is far safer to rely on the "cost sense" of a capable and experienced foreman than on the "cost nonsense" of an inefficient clerk.

Assuming, however, that accurate cost data are required, for purposes of estimating and as a continuous check on the relation between output and cost, it is first necessary to classify the various expenditures so that they may be properly recorded and analysed. The primary broad classifications of expenditure in a foundry are as follows:—(1) Labour costs; (2) material costs; (3) cost of installing, equipping and maintaining in efficient condition the necessary buildings and plant; (4) management, clerical work, and selling costs. Each of the above has its subdivisions, quite apart from any division relative to a variety of product. These subdivisions will be dealt with later. The first consideration is to ascertain how far the particulars of the above classes of expenditure can be determined in the foundry, and how far they must be supplied from other sources.

FORM 3.—CUPOLA CHARGE SHEET.

Name Date

Kindling Material. Bed Coke		lbs.	£ s. d.	Mixture
Charge No. 1 ..	Pig			
	„			
	„			
	Scrap			
	„			
	Coke			
	Coke from bed			
Charge No. 2. ..	Do. do.			

Expenditure on labour can be entirely ascertained in the foundry itself, for it is there that all the labour is expended and should be recorded, the total being, of course, the total of the wages sheet. Expenditure of material (so far as quantities are concerned) is also within the cognisance of the foundry manager, though under some systems of business organisation the costs of the material are not always known to him.

Cost of installing and equipping the foundry may or may not come under the foundry manager's notice; it is immaterial, provided he records any interior expenditure on maintenance or repairs which involves his shop's labour and materials. Management, clerical and selling costs need not be known in detail by the foundry manager; it is sufficient for works costing if he is informed of the total periodically.

It is seen, then, that the first two classes of costs are essentially the concern of the foundry manager. They may therefore be examined as to their incidence or relation to distinct classes of foundry operations. The subdivisions of foundry work which involve expenditure of wages on labour are:—(1) Moulding; (2) core-making; (3) sand treatment; (4) metal melting; (5) fettling—cleaning and dressing; (6) conveying—crane work, etc.; (7) other operations, such as labourers' general assistance; (8) local supervision by charge hands; (9) general supervision. A proportion of each of these is related to each job or class of work in the shop, and the method of cost recording should as far as possible determine the extent of the relation. Some items cannot be allocated to jobs in absolutely correct proportion, while others, such as moulding and coremaking, involve direct expenditure on jobs, and can be determined exactly. The first essential is that all time spent in the foundry and paid for be recorded definitely and with as comprehensive details as possible.

For the sake of convenience the iron foundry can be taken to illustrate the principles under discussion, which principles also apply to non-ferrous work; and a foundry doing a mixed class of work will be considered.

Before discussing the methods of recording costs, however, it is well to outline a suitable method of dealing with orders received. It would be foolish to lay down hard and fast rules for all establishments alike, but in essentials some such system as the following is necessary, particularly where both heavy and light castings are being made.

When an order for manufacture of castings is received, the order should be given a Contract Number, covering all work to be done for the job in all departments. Next, the work should be analysed, and that for each department set out in writing. The instructions for all the necessary patternmaking and foundry work should be passed into the shops, stating the same contract number on each separate instruction. Since many contracts will comprise more than one distinct class of work, each separate and distinct job should be given a serial Job Number, which could then be used throughout the operations to completion, to designate all work and expenditure on that job as distinct from any other. All instructions issued to the foundry should then have the Job Numbers clearly shown, so that any expenditure incurred direct can be charged to the job in the costs records. Also, the foundry manager's orders to his sub-departments should explicitly state the full particulars of Job Number, etc. In this way all cost records will relate to jobs and not to contracts, and can later be assembled to determine the contract costs.

Instructions having been duly given for the conduct of the work, the next essential is to record the details of labour expended on each job. There are various methods of doing this, but probably the most useful is that involving a daily time slip, ruled similar to Form 5. Every man (including charge-hands and foreman) should each morning receive from the cost clerk a Time Slip with his name, number and date filled in, and every charge hand should see that his men have their

FORM 4.—MATERIAL CONSUMPTION SLIP.

Date.

Materials. ..	Quantity	Job No.
Requisitioned by Charge hand	Issued by Storeman	

FORM 5.—TIME SLIP.

Name Date

	Hours.	Rate.	£ s. d.	Job No.	Moulds made	Moulds poured
Moulding						
Coremaking						
Pouring						
General Labour ..						
Supervision						
Total						

Charge hand's initials

slips. Each man should then have the number of his job written on his sheet by the charge-hand or chalked on a board at his place, bench or machine. In the case of repetition work the job number, number of moulds required, and any other instructions should be given to the man in writing or chalked on a board for his notice. This saves a lot of confusion in recording work. The completion of the details on the Time Slip is a relatively simple matter, provided that similar instructions are given at each change of job, which in some cases may occur several times a day. However, as many men are inherently careless or incapable of properly recording their time, the charge-hand should make it his business to inspect the slips of his men as he collects them each evening, check the entries and initial the sheets as correct. This may seem like putting clerical duties on the charge-hands, but they alone can check the records of the men's time, and can do so in a few minutes each day. It also draws their attention to any over-expenditure of time on a job, or waste of time between jobs.

Form 6.—Sand Mixer's Record.

Date.

Name.	Hours.	Rate.	£ s. d.

New Sand used.

Class of Sand	Amount.	Price.	Value.	Job. No.

somewhat in different shops, but the method of treating the work for costing purposes is in principle the same.

Taking first cupola work, we may discuss a method of allocating this cost to the jobs concerned. The best method of dealing with the cost of cupola operation and similar work is to treat it as a separate class of productive work giving a product which can be charged to jobs the same as any other material, the charge being based on quantity used and the ascertained cost of producing. It is a bad principle to ascertain the general cost of producing metal and then charge on that basis. The cost will vary from time to time, according to the class of mixture, the length of heat, and from other causes. Therefore, a daily cost in relation to a daily output should be aimed at.

The first essential is to determine the total cost involved in producing molten metal at the cupola spout, and the next to subdivide this cost as far as possible. For job cost purposes the labour need not be subdivided according to its operations, as

Form 7.—Fettler's Record.

Name Date

Job No.	Date Poured	Good Castings		Defect: Castings		Total returned Scrap	Hours	£ s. d.
		No. of Pieces	Net Weight	No.	Net Weight			

It is obvious that the allocation of cost of labour and material direct to job numbers is limited to certain classes of expenditure, in which the proportion of expenditure incurred by each job is distinct and separate. Such classes include pattern-making, moulding, coremaking, stripping, cleaning, fettling and despatching. Other classes, however, involve expenditure in bulk for a variety of jobs, examples being cupola work (including preparation, charging and melting, and the materials involved), sand mixing, certain kinds of incidental labour, crane operation, supervision. The exact variety and nature of this class of work will vary the total of cupola labour can be divided over the output on a weight basis; but it is desirable, for the purpose of obtaining technical data on the cost of cupola maintenance, to record separately the time spent on repairs and relining, also the materials consumed in that work.

The daily completion of the Cupola Time Sheet shown in Form 2 (or any similar record) supplies sufficient information on the labour expenditure. The materials charged, however, are more difficult to record; but a Cupola Charge Sheet similar to the one shown in Form 3 should, if properly filled, meet the case. The foreman dictating the nature

of the charges should write down for the guidance of the cupola man the metals and amounts to be used in each mixture (where more than one mixture is run in the course of a day's work), and should also give each mixture either a name, number, or letter of reference, which should be in turn entered on the Cupola Charge Sheet. The object of this is to associate the particular charge with the job for which it is intended.

The particulars set out on the specimen Cupola Charge Sheet, Form 3, are only those required for costing. In addition, there should be recorded further details of time of blowing, blast quantity and pressure, etc., though these are not required for costing purposes.

The cost of each mixture melted can be ascertained from the cupola records, also the quantity of materials consumed. From this can be obtained direct the cost of the total metal issuing from the spout, and from the fettler's records of castings passed on to him can be obtained the net weight, plus returned scrap, of metal in each of the jobs cast on any date. It is a simple matter then to distribute the cupola gross cost in the same ratio.

When metal is poured on to the floor for remelting, on account of defects relating to a specific job, the weight returned to the cupola man should be charged against the job at the day's cupola metal cost rate, and then be credited to the job at shop scrap value; but on the job cost sheet it should be shown as a special item under "Other charges," to prevent over-estimating the metal required for future similar jobs. If, however, metal is scrapped by reason of over-melting or cupola defects, it should be similarly charged to the "General" cost sheet, and the shop scrap value credited thereon. Metal and coke salved after dropping the cupola bottom should be credited to the cupola consumption for the day.

In order to ascertain the daily or "heat" cost of cupola operation, the cupola day should be regarded as commencing from the end of one heat (dropping of the bottom) to the end of the next. Time may be spent in the latter half of one actual day in preparing for the next day's heat, and should therefore be charged to that heat.

Sand-mixing, next, is a class of labour which cannot be readily apportioned to jobs direct. Such mixing and preparing as is not done by the moulder himself for his own job should be separately recorded, and the amount in cwts. (or any suitable quantity) of dry sand used for each separate mixture should be stated, with the day's labour distributed over each in proportion. Special mixtures for particular jobs can readily be separated in the mixer's record, and the labour and material charged direct to the jobs. Where bulk quantities of sand are prepared for general work, the total should be recorded and the cost distributed over the jobs in proportion to the weight of untrimmed castings moulded, as that will give the nearest approximation to the amount used in each class of mould.

Under a proper system of organisation there should be very little labour expended on indefinite work, *i.e.*, on such operations as cannot be designated by a job number, and such labour should be booked up as "General," and distributed with the cost of shop supervision on the basis of wages paid on the different jobs.

Crane man's time in a shop doing miscellaneous work must not be booked up as a general charge to all the work. The actual operating time may be only three hours a day, but the crane-man should be told the number of every job he handles, and should then book on his sheet the actual time expended at each job. His whole day's wages (if he is confined to the crane all day) should then be distributed in the same proportion over those jobs served that day, crane work being treated as a service retained for just those jobs actually using it.

FORM 8.—CUPOLA COST SHEET.

Date	Net Materials	£ s. d.	Labour £ s. d.	Totals £ s. d.	Transferred to Jobs. Job. No.	Net lbs.	Scrap lbs.	Total lbs.	Charged £ s. d.
	Charge 1 ..lbs.								
	Charge 2 ..lbs.								
	Charge 3 ..lbs.								

Supervision may be partly allocated to jobs and partly to general charges. In the case of general supervision the time should be booked as "Supervision" wages on the "General" cost sheet; but in the case of charge hands' time where a definite set of jobs is under his care, this should be charged to the jobs in proportion to the wages expended on each. This can be done daily or weekly.

Fettler's records should include more than actual time spent in trimming and cleaning work. Each casting or batch of castings sent into the fettler's room should be accompanied by the job number or numbers and the date of pouring, and after completion of trimming the net weight should be recorded, together with the time expended and the net weight of returned scrap, such as heads, risers, etc. A suitable form for the fettler's use is shown in Form 7. Any defective castings discarded in the fettler's shop should also be shown on the fettler's record. Should any casting be scrapped on later inspection, a voucher should be filled in, stating job number, amount scrapped and weight of scrap to be credited to the job. The cost of re-making the casting should be charged to the job, and special note thereof made on the Job Cost Sheet, Form 9.

When such material as grids, gaggers, etc., are made for a job, they should be treated as a

separate supplementary job, and be given an "S" number. For example, grids for Job 74 would be Job 74S, and be costed separately for labour and material, to ascertain their value, and then be transferred to the cost sheet of Job 74. If after use they are still good, and likely to be usable again, an estimated value (according to their likely use) of not more than 50 per cent. of cost, should be given them; that value credited to the job and debited to stock of wearable equipment, and the stock list entered accordingly. When such equipment is damaged it should first be charged against the job at its full cost, and then be credited to the job at scrap melting value, and treated as scrap metal. On receiving data of an "S" job number, the cost clerk should ascertain from the shop what value is to be given the material after use.

Mould-drying and core stoves should, like the cupola, be treated as separate departments, giving service at an hourly rate, dependent on the cost of operation. Any suitable form of record can be compiled, according to the conditions existing, but it should show the daily expenditure of labour, fuel and any other materials. This would give the hourly or daily cost of the service, and each day's total cost should be distributed over the jobs served. For this purpose, when cores or moulds are sent for drying, they should be accompanied by their respective job numbers, and the approximate time in the oven recorded. This, in conjunction with the approximate space occupied, will allow a rough daily allocation to different work of the total cost of operating the stoves. Whatever quantity is stoved on any day, that day's total cost must be distributed over the jobs concerned. This can be quite well done by the cost clerk if the particulars are duly recorded.

All consumption of materials drawn from stock (other than cupola charges and sand), should be recorded on the Materials Consumption Slip, Form 4. If this is filled in by the charge-hand requiring the material, and sent to the storekeeper, the slip serves the purpose of both a requisition and a record. This procedure prevents wastage of material by unauthorised persons, and assists in the recording of consumption. As before stated, these slips, passed daily to the cost clerk, allow him to record all consumption of materials and keep his stock sheets in order.

When all the foregoing data has been compiled each day and passed into the office, the costing clerk can then proceed to transfer each item of cost—labour or material—to its proper Job Cost Sheet, some items, of course, going first to the intermediate account (such as Cupola Cost Sheet, General Cost, etc.) for distribution. These latter accounts, naturally, have first to be completed. For example, the cupola charge sheet is taken, and the cost of the materials consumed is entered, distributing the cost of bed-coke and kindling over all the charges, and deducting the value of recovered coke and metal (these credits also being distributed over the charges). Each charge will then have a total value and weight which can be transferred to the Cupola Cost Sheet, and posted against the charge numbers. The Cupola Time Slip should then be completed, and the wages distributed over the charges in proportion to their weight.

The sand mixer's record next should be taken, if that work is done as an independent operation. The value should be filled in, and if the job numbers have been known and already stated, it is a simple matter to spread the labour over the lot, and post the totals to the Job Cost Sheets.

These having been completed, the cost clerk can then proceed to post up the Job Cost Sheets. Labour shown on the Time Slips with a job number can be posted direct. Other labour, such as supervision, must be posted on to a "General" cost sheet for distribution over the various jobs in proportion to the wages paid on them.

Pouring time, of course, often cannot be allocated to jobs direct. It is necessary for the cost clerk to take the total time each day or week recorded for pouring, and spread it over the jobs concerned, in proportion to their moulding time. This is not, perhaps, a strictly accurate basis, but it is probably the nearest possible, and is never far out.

The Fettler's Record (Form 7) gives direct the labour cost to be posted to each Job Cost Sheet. It also gives, by adding the weight of good castings to the total returned scrap, the amount of metal poured for the jobs on each day. As the fettler will generally handle the castings on a date subsequent to pouring, he should insert the date of pouring as given to him when the castings are passed on to the fettling room. This enables the weights to be posted against the correct day on the cost sheet. The delay in obaining these figures of weight means that the metal used cannot at once be recorded, for this information is required in posting the Cupola Cost Sheet. To deal with the latter it is necessary to collect the weights of all jobs poured on a given day, and distribute the net weight from the Cupola Cost Sheet in propor-

FORM 9.—JOB COST SHEET.

CONTRACT NO. JOB NO.

Details of Job.

Labour					Materials			Other Charges		
Date	Moulding	Core-making	Fettling	Total	Date	Description	£ s. d.	Date	Description	£ s. d.

tion to the amounts shown by the fettler's records. This may seem a complicated method, and in straight runs of work it can be avoided by a simple record of metal melted, and a distribution over the weekly net production of good castings. With very mixed types of work, however, the latter method does not properly distribute the melting and pouring loss, and the relative cost of melting heads, gates, risers, and scrapped castings. The method described automatically accounts for these losses and costs in actual ratio to their cause.

Various material consumed, other than metal and sand, is posted direct from the Material Consumption Slips, or alternatively from the stock records.

Pattern costs, crane-man's time, packing, etc., can also be posted direct from the daily records. The same applies to cartage if paid for direct, and in the case of using the firm's own vehicles, an hourly charge should be made by the department for the vehicles.

Taking next the standing or overhead costs of the foundry, these include such items as rent, rates, taxes, heating, lighting, office and management expenses, insurances, etc. These costs can nearly all be determined in advance, or else are related direct to the wages paid weekly. They should be carefully analysed, and the yearly or periodical total divided up to give, say, a monthly figure (or even a weekly figure), so that the latter amount can be distributed on the jobs, on the basis of the wages paid. Overhead charges should be reduced to a minimum in number, by eliminating any such costs as inward carriage on material, labour in handling, etc. These latter charges should be recorded and added to the cost of the material, and not be posted to any other account. They thus get on to the job costs in strictly correct proportion.

Supervision and unallocated labour of all descriptions should be distributed over the jobs weekly, in proportion to the other wages paid on each job, and should not be put under standing or overhead charges

The foregoing outlines the principles of a system, the details of which may be simplified or extended according to the nature of the work being done. The system is not proffered as a rigid one, as it must obviously be adapted to requirements; but in any case the principles set forth should be carefully observed.

Discussion.

The CHAIRMAN said Mr. Hayes had gone into the subject in great detail, and it required the enthusiast to properly appreciate the lecture. There was one man in the system who was going to have a really busy time, and that was the costing clerk.

MR. HIRD said he was just in the thick of a new system of costing. It would take some grit to pull it through. Amongst the ment at present there was a strong epidemic of fed-uppishness. New systems made it necessary to take out a lot of old practice, and if anything was to be done on modern lines old methods must be scrapped and a lot of clerical work taken on which the moulder did not like. The results always gave one the "pip," as they showed things had been going in a way of which one had no idea. No doubt a proper system was essential, in spite of the difficulties. One difficulty was inspection of patterns. Sometimes two, three or four hundred castings were made, and then someone came from the machine shop and said "Stop; they are all bad; there is a mistake in the drawing office; there ought to be a boss on here, and it has been left off." Unless things were checked one ran up against serious difficulties. In the system he had mentioned cards were used. The foundry manager had one card which each day was posted up with a complete record of every job, showing as far as possible the cost, the weights and everything. A matter the author did not mention was this: He (the speaker) was introducing lockers for the moulders. There had been much loss of time and great annoyance through moulders running about for things they wanted. Enough bellows might have been issued, but somebody might have run some metal into a couple of pairs, or they could not be found. It was common to see a man wandering right up the shop to find a pair of bellows. Lockers with keys for each man were being instituted, and each man would be given a set of tackle for which he would be held responsible. It helped a man to become tidy and systematic. In his shop they were following a laboratory system. Everything would fail unless one knew what particular mixture was used for a particular casting, and on what day, and to get such a record they were starting a system of data for casting, moulding, etc. For machine casting the date, as well as the pattern number, was recorded. Moulders working on the floor would have a little stamp. They were taking the letters of the alphabet: A for January, B for February, C for March, and so on. It might be two or three weeks before a casting was turned up in the machine shop, and if there was something the matter with it one might wonder what was put into it, and when it was cast. Unless one had those particulars a system of record keeping was rather useless.

MR. BARTLETT said in regard to a good many items he agreed with the author, but he thought he had gone in for a little too much detail for the majority of them. He agreed that the wages basis was the right one, but when one came to charging the crane that had been doing three hours' work in the day on three jobs it seemed rather heavy for those jobs. Possibly the crane driver ought to be brought down on to the floor and be given something else to do. Charging the cost of the cupola charges to the jobs produced on a particular day seemed a rather unfair basis, because on one day one might be running a lot of light castings and the next day a lot of heavy ones. A man could not be taken away from the cupola and given something else to do because though only 8 tons might be run one day there might be 50 tons the next. He might be scraping up the skins from the cupola floor on the slack day ready for the heavy day. It was a question of shop management. How did the author distinguish between productive or non-productive charges?

MR. CLEAVER thought even when one had the record of costs it could not be relied upon as being correct. Too much was left to the moulder, core maker, sand mixer, crane driver, cupola man and fettler. He thought there must be some simpler method for general foundry work. It might be all right for straight engineering concerns. Take a moulder with 30 patterns, with various numbers off each pattern. He did not know who was going to make his time-sheet up. A staff of clerks would

be required to regulate job numbers. Was it fair to charge the returned scrap to the actual job? One got a run out or bad castings about which nothing was known for a month or two, and a certain amount of scrap went down from the cupola to the floor. He did not know how that was to be allocated to individual castings.

MR. NAISH said the subject deserved more serious consideration. While it was a little complicated for small foundries, he thought some such system must be used for larger foundries. There had been too much of haphazard methods of working. He believed the things the author proposed were done, and done accurately. Some system should be gone into, but whether this system was the best for small foundries was a matter of opinion. The author wanted to charge the time of the core-making and drying to the job—to take the time the cores were in the oven, and so forth—but often the cores were left in the oven till they were wanted. That was rather a difficulty.

MR. BARRETT agreed with the author that the man responsible for the foundry should have the choosing of the materials. It was most appalling in some foundries to find people ordering stuff who did not know anything about it. They ordered it because a traveller told them a "fairy tale." He (Mr. Barrett) did not see how the consumption of the coke fires of the core ovens could be separated for the jobs. That would not suit him, as he had in his core ovens sometimes 600 cores. It would be difficult to separate the core drying costs for the jobs, especially where there was a great variety of castings on a plate. He might get four castings on a plate and a range of 20 castings. He had to change his patterns and the man went on again.

MR. WILLIS said the subject was a serious matter, and, if solved satisfactorily, would save a lot of trouble to foundry foremen and managers. Up to the present there had been no accepted system giving details of each job or each class of articles made, more especially in small foundries and in large foundries dealing with small work. The difficulty was in the interlocking of labour. The trouble was to separate the labour, even with this elaborate of system of job numbers, time cards and forms. Could one really depend upon the actual time worked being properliy allocated to the jobs by the operators themselves? It would also be a stupendous job for the cost clerk to get all the information together and charge it. Many years ago a firm he was in made up their minds to adopt an American system of job numbers and job sheets. Previously, in some departments, but not in the foundry, they had a board with the men's names and the jobs they were on, and the foreman chalked on it the number of hours they spent on each job. When the new system was introduced with large sheets, every job had a number, and the men were to put down what the job was, how long he spent on it, and when it was brought into the foundry. Some moulders had 40 patterns in a day, and the men refused to attempt to describe what the articles were and what job they belonged to. He agreed with the author about the outside interference with the foundry foreman or manager. Materials were bought and terms and conditions of work were laid down which were out of all reason for the practical man. He could not agree that the author's system was what he would call a good one, and he did not know that one ever would be found to deal with the details. It might be satisfactory where the jobs were kept separate—where a moulder kept on a particular casting or run of castings. The time of the moulder, trimmer, or fettler, could be allocated, but he did not know that the core-maker's could, and he thought the crane, the cupola, the sand mixing and the handling of materials would have to go into a general charge and be allocated by weight of castings turned out, or else, according to the wages cost of the castings, turned out. He thought a simpler method must be adopted for charge hands and men to carry it out.

MR. SLATER thought the author's system should be very useful. When a job came in the cost office had its order, and issued an order to the foundry. That order could be put in a book under its current number, and also in a book under the name of the customer, so that it could be turned up in either way, and the general record should embody cupola men's labour and pouring, in the cost under one charge, and cost of carting materials. He thought that was sufficient for any foundry foreman to know. It was handy when one was heckled on any particular cost.

MR. BARRETT asked where the analytical and mechanical tests would be placed in the records?

MR. WILLIS said he thought Mr. Slater had missed the point. The point of the Paper was to get at the real cost of the casting. The old system was to get the cost in at so much per lb. or per cwt. and give the benefit of the extra weight and cheap production of the heavy castings to the people who had the light castings. The people who had the light casting were not charged the proper amount of cost, because there was not a proper system of allocating the costs. A system might be devised under which Mr. Slater's ideas would be sufficient for the foundry cost as the approximate cost to the firm, but with that it was necessary to have an analysis of the real cost before the bill was made out for the customer.

The AUTHOR, replying to the discussion, said he was afraid he had "drawn blank." He was hoping to get constructive criticism. The experience in that room should have produced at least some semblance of an accurate costing system, but no suggestion put up had any relation to the obtaining of cost figures. He did not agree with a criticism from Major Gordon on the paper question. The actual cost of paper involved was trivial. There must be thousands of concerns in this country issuing daily time slips on which the men recorded their day's work, and the system he proposed only meant one slip per man per day, plus one sheet for the cupola, one for the drying stoves, and probably one for some other department. The expenditure only amounted to a few shillings per week. He appreciated that there was a good deal in the system that Mr. Bartlett could not accept, because it was impossible for anybody to outline a scheme, except on broad principles, which would apply to every class of foundry. He was up against a difficult problem in tackling London, because London was notorious for having foundries with trifling one-off jobs. The majority of them did nine classes of unsuitable jobs for every one they were justified in touching. Running 30 to 50 jobs a day with probably only a few moulders operating could not be done economically and could not be costed well. One could only trust to luck and have a big margin for contingencies. Experience might show that some work was worth 3d. a lb., and some 6d.

It was a difficult proposition to apply a strict costing system to that. He did not agree that even where there was a great variety a cost system could not be adopted. If one had 100 jobs in a day they could be classified into batches of work of the same nature, and a batch could be treated under one job number for cost purposes. Pattern-plate work of a certain type and oddside work all of one class could be lumped for costing purposes. It was a simple matter to modify a system, to mass the work and cost in batches, but that did not affect the final distribution of the cost over the jobs. When foundries got on to a reasonable system of handling stuff in reasonable quantities instead of getting a mixed pickle of stuff in every shop, the system he suggested was workable. He himself had recently been purchasing in fairly large quantities a selection of small brass parts, all in a general classification of the same nature, but there were two or three of these for which was determined the absolute cost by a system similar to the one he had described. One casting weighed 1 oz., and could be produced, machined and all, for 1s. 3d. That was a paying price. Another weighed ½ oz., with very little machining, but it could not be produced to pay at less than 1s. 7d. The relative values by weight of those two castings were 1s. 3d. and 3s. 2d. That was an example of the discrepancies one got. That was why one should adopt a form of costing which gave piece or job prices, instead of prices by weight. In regard to crane work, it was not fair that any job which did not require crane work should be saddled with crane charges. He perhaps exaggerated in referring to three hours out of the day, but the services of the crane were distributed over, say, eight hours, and the actual time of operating might easily be only three or four hours. It paid better to keep the man on his crane than to have two or three moulders kept standing still while he was fetched. It might be necessary under some conditions to modify the cupola costing. If the cupola were run for half a day on light work, and then shut down to prepare for the next day's work, it was easy to record the labour of preparing the next day's charges against the metal produced the next day. The labour involved in any heat should be charged to the jobs using that metal. It only required a little intelligence in recording the figures and distributing them afterwards. With regard to the clerical work, where a man handled 30 or 40 jobs a day his work must be lumped, and work of the same nature treated as one job Most men, under proper working, would not get more than from three to six entries a day on a sheet, and that only when they changed from one job to another. Similarly, in regard to the core ovens, if there were a varied run of work, the system must be modified to suit it. It was not up to an outsider to give every foundry a complete system. The final organisation was a matter for the foundry manager or somebody in charge. Core-oven charges could be allocated properly. A large core which was in the oven a whole day or a day and a half or half the day and all the night incurred a high fuel cost. If one got into the way of lumping all the core-oven costs and spreading them over all the jobs, they might be put on jobs which required only a few hours. Jobs that did not require the core-oven service should not be charged with it. With regard to the laboratory work, it was not safe to assume that any job was not using the service of the laboratory. It was there to provide information, and though the information was obtained by testing certain jobs it was applied to every job, and therefore laboratory charges should be a general overhead charge to be distributed in proportion to the wages or any other basis chosen. There was no such thing as unproductive work in a manufacturing shop. Even the work of the cost clerk was productive in so much as he provided the founders with information which enabled them to work at a lower cost. He did not agree that the terms productive charges and unproductive charges should be used. The only distinction was allocatable and non-allocatable labour.

ANNEALING TOOL STEEL.—Carbon tool steel, as it comes from the forge, has a distinct crystalline structure, as is well known. Some useful suggestions in this connection are to be found in a recent issue of the Journal of the American Steel Treaters' Society. The smaller the size of the crystals in carbon tool steel the lower is the annealing temperature required to break them up. This temperature ranges between 1,400 deg. and 1,500 deg. F. If the steel has been overheated in the forge or mill, the grain may be coarser, and it may be necessary to exceed 1,500 deg. F. to break it up properly. It is important to do this, as otherwise the steel will retain lines of weakness due to the cementite in which the grains are embedded. The crystalline structure having by the heat treatment been broken up, the desired machining qualities are produced by appropriate cooling. The more slowly the steel is cooled through the critical range and the 300 deg. or 400 deg. below the softer it will be. If the cooling be too prolonged, the usefulness of the steel will be destroyed by throwing the carbon out of combination with the iron. The annealing must be stopped at the point where the carbide or cementite has all been reduced to the globular form. The effect of tungsten is to hold the carbon in combination with the iron, and thus to prolong the time required for cooling.

AN ELECTROLYTIC METHOD FOR DETERMINING CARBON IN STEEL. — A method new in principle and extremely simple, has been recently brought out by J. R. Cain and J. C. Maxwell for determining the amount of carbon in steel. It is claimed to be accurate within 0.01 per cent. The details were published by the authors in the September, 1919, issue of the "Journal of Industrial and Engineering Chemistry." The fundamental principle of the method, which, it is believed, is of wide application, is the change of electrical resistance brought about in a standard solution by the precipitation into it of another substance. This substance is in this case carbon dioxide, obtained by direct combustion of the metal. The standard solution is barium hydroxide, of known electrical resistance. Hence the underlying chemical equation is:—$Ba(OH)_2 - CO_2 = BaCO_3 + H_2O$. The increase in the resistance is due to precipitation of barium ions. Not only is the principle new, but the assembly of apparatus is also new, and offers many advantages for technical work over the methods hitherto in use for the measurement of electrolytic resistance. These require a complicated and expensive set of apparatus. Other new features are. The application of the "nomograph" for the graphical representation of resistance data, and the use of special conductivity cells with adjustable electrodes to facilitate the manufacture of any number of such cells without the same cell constant. The purpose of the authors' study was to investigate the accuracy, speed and practicability of the method. A suitable absorption vessel, with electrolytic resistance cell incorporated is described and illustrated, as well as the method of combustion adopted.

Education in Relation to the Foundry Trades.

By B. Whiteley.

Part I.

With the signing of peace there approaches the time when the Education Act of 1918, which for the first time deals with the problem of the after-school training of young people and adolescents in a manner which may be considered at all with satisfaction, will be put into operation. When its action has become fully developed, this Act may be expected to work a revolution in our educational system, and it is the purpose of this article to deal briefly with the purpose of the Act and the manner in which it may be brought into operation, the effect it may be expected to have upon the foundry industries, and the means which the industry in its various branches might take to obtain the most satisfactory results from its operation.

In the first place, it will be well to have a general knowledge of the scheme outlined in the Act as a starting-point from which to discuss its bearings upon the foundry trades. The first important point is that after the appointed day young people who attain the age of fourteen years shall be under educational training from 280 to 320 hours per year, and that this training shall be given during some part of the time when previously they would have been employed in the works at which they are employed; but that for a period of seven years this obligation shall not apply to young persons between the ages of sixteen and eighteen, nor at the expiration of that period to those who at the expiration of that particular time have attained the age of sixteen. It may be required by the Local Authority that, in order that the young persons may be in a fit mental and bodily condition to receive the full benefit from such attendance at classes that their employment shall be suspended, not only during the time when the classes are in session, but for a further specified period not exceeding two hours—which in effect means that any youth being in attendance at a morning class will not engage in work before proceeding to the class; or, being in attendance at an afternoon class, will require a period not exceeding two hours after the morning's work to prepare himself for his studies. No classes will be allowed before eight in the morning or after seven in the evening, nor on Sunday or any day exclusively set apart for religious observance by the religious body to which the youth may belong, nor on any of the statutory or agreed holidays pertaining to his employment; and provision is made to enforce attendance at the classes which are arranged by the Local Authority, or by any firm under agreement with the Authority, by the infliction of fines for non-attendance, except for sickness or other unavoidable cause.

It will be the duty of every Local Education Authority to formulate schemes which shall embrace the formation and maintenance of these classes or schools, and the arrangements for study, instruction and physical training carried on in them, and in the doing of this shall consider any representations made to them by parents or any body of persons interested in this work.

It will be appreciated at once, from this brief outline of the Act as it refers to Continuation Schools, that it marks a great departure from previous methods, and that its present effect upon industry needs to be considered and plans made so that the absence of apprentices for some period of each week will not prejudicially affect the management of any works. It will be acknowledged that, if properly carried out, it marks a great step towards the attainment of that ideal which has been frequently put forward by enlightened employers and workmen alike, that the future workman shall be more intelligent and better trained in all ways than his predecessors have been, with a broader outlook, and consequently a far better conception of the difficulties and problems which are in front of present-day industry. This question of training has been before the notice of the Institute of British Foundrymen, and steps had been taken by that body before the passing of this Act for the better training of apprentices in the foundry industry. But these suggested plans had been devised for the training of those who had begun work in a foundry and were to be expected to remain in that trade, and had to some extent been forced upon the industry by the gradually diminishing number of youths entering the trade.

In this connection, what may be the result of these continuation schools? Will it possibly increase the number of entrants into the trade, or will its effect be to accentuate the dislike of youths to enter the foundry? It is very possible, and indeed very likely, that its immediate effect will be to diminish the number of youths who will continue to work in the foundry. The young foundry apprentice—if that name may be applied to a youth whose duties may consist of sand riddling, or errand running, or any of the multifarious jobs which new-comers in the foundry are set to do—will for a certain part of the week be mixing in class with those who may be employed at lighter or cleaner jobs, and he may decide that he also greatly prefers one of these jobs and forsake the foundry. To some extent he would be amply justified in his decision, as the conditions obtaining in some foundries are such as would repel the more steady and intelligent youth, who is the one whose presence in the foundry is most needed. The demands made upon the foundry by the other branches of engineering are steadily rising, and perhaps no section of engineering practice really needs the trained intelligent workman with initiative as does the foundry, and probably no branch of the industry obtains so few workmen of this type. In so far as the conditions of labour in the foundry tend to curtail the supply of really efficient and trained minds, such conditions will require to be remedied, but, possibly, one of the immediate effects of the mingling of youths of varied occupations in these continuation schools will be a falling-off in the supply of labour coming into the foundry, or the driving into the foundry of the type of youth who is least capable of mental development. It will rest with the industry to devise such reorganisation and improvements in methods of working as will attract rather than repel the youth who has some amount of initiative and capacity for development.

Whether these continuation schools will fulfil the purpose for which they are intended or no will depend very largely upon the ideal which animates those who draft out the schemes by which

for some years at least the educational policy of these schools will be guided. One of the greatest defects of our educational system has been that it has produced in the minds of a great number of people the idea that it is much more respectable to be able to obtain one's living while wearing a black coat and keeping one's hands clean than in any other way. This is probably because our educational system in the main laid special emphasis on the study of books as the means of obtaining knowledge, rather than on the study of things. It is true that this idea is not so prevalent now as formerly, and that all the real educationists of to-day insist on the study of things equally with, or even more than, the study of books, but it is certainly also true that to the great majority of people school and books are almost synonymous terms. And running through the minds of a great many people has been the idea so succinctly expressed in the phrase "knowledge is power." As with many other of our common proverbs, this does not express the whole truth. Knowledge of itself is not power, but the power comes by the ability which a person possesses to use the knowledge he obtains. It is of no avail to fill a head with knowledge, unless in the doing of this the mind is so exercised and trained and developed that it can utilise the knowledge it possesses, and by means of this training and development can reach forward to other and higher knowledge. The wording of the Act is that the Local Authority shall supply and maintain continuation schools "in which suitable courses of study, instruction and physical training are provided"; and if the schemes worked out in these schools provide for the real mental and physical development of the youth from fourteen to sixteen they will undoubtedly increase in a marked degree the brain power of the country. It will be of value if various associations in connection with the industry present to the various Local Education Authorities their ideas in connection with the training of the faculties required in their works, as such knowledge would enable schemes to be worked to their best advantage. It must be understood that these continuation schools, *i.e.*, with pupils of from fourteen to sixteen years of age, will not be vocational; they will not necessarily train the pupils in the business or trade in which they are engaged. In a district where the industries are of a mixed character this would probably be impossible, and, if possible, would not be desirable, as what is really required is not to teach the principles of any business at that early age, but to develop the powers of intelligent observation, perseverance, and sound reasoning which will enable the youth in later years to tackle and overcome the problems which will face him either in his work or in his leisure hours.

It will be obvious that the success of these schools will also depend largely upon the quality of the work done in the Elementary Schools from which all the pupils of the Continuation Schools will come. It is really surprising, when one thinks of it, how little is known of the work and organisation of the primary schools of the country. Considering that for nine years the children of the country are daily attending school, this lack of knowledge concerning the public primary schools is almost appalling. Unless there is a clear conception of the steps that have been taken in this country to develop a system of education, there will also be the danger that the most beneficent plans devised by enlightened educationists may be thwarted or distorted so as to produce results which may have effects the reverse of beneficial to the community. A general outline of the progress of educational effort during the past half century or more will thus be of value in enabling a right estimate of present-time proposals to be obtained.

In the years preceding the passing of the Elementary Education Act of 1870-71, the Governments of the day assisted education by giving grants for the assistance of the schools which were already in existence, and for the provision of new schools where no such institutions existed. The total inadequacy of this proceeding, and the illiteracy which marked a great portion of the population impelled the Government in 1870-71 to pass the first Education Act, and compel the formation of School Boards in those districts where the accommodation for educational purposes was lamentably lacking. In a comparatively short time the country was covered with a network of schools, many carried on in premises which eventually proved unsuitable, but which, at all events, brought some form of education within reach of the great mass of the people. But along with the formation of schools, the acquisition of knowledge as such was strongly insisted upon, and reading, writing, and arithmetic were made the foundation—and the topstone—of the structure, while at the same time it was considered possible to assess the work done by the teacher as reflected by the results obtained in an examination of the children's knowledge made by a State official, and grants to schools were paid upon the results thus discovered. The immediate result of the working of this system was the undue importance placed upon mechanical work in the production of prodigies who could read fluently with little appreciation of what was read—still a common failing—who could perform wonderful feats with figures without understanding the reason of the process used, and who could write a beautiful hand whether they could express their own thoughts or not. Very little real mental training was or could be given under these circumstances, and in a large number of instances the main idea of the pupils on leaving school was to try to forget all that had been so painstakingly drilled into them. Such, after all, could only be what might have been anticipated, because, however possible it may be to assess and reward work in the material world on the basis of payment by result, it must be realised that in the realm of mind such assessment and payment is utterly beyond the power of even an official of the State. This false bias given to education has not even at the present time lost its force, and many people, some of whom ought to know better, criticise present-day education on the ground that certain specified results which can be tabulated and graphed are not now obtained as they were formerly. Too much stress may easily be laid upon the exhibition of knowledge in certain specified ways, and probably this is done even yet in the multiplication of examinations and the worship of results in the secondary and higher branches of our educational system. Frequently one meets the individual who perhaps, owing to later or slower mental development, was considered a failure during his school career, but who made a mark in later life. This is often owing to the fact that provision is not yet properly made in the school curriculum for pupils of that type.

The growth of higher ideals concerning the real purpose and meaning of education, that is, that

it does not consist in filling the mind with knowledge as one fills a tank with water, but that as the word implies, it is the drawing out and developing of the faculties of the mind which each possess in varying measure, compelled the abolition of the system of payment by results towards the end of the century, and since that time there has been a great broadening of the curriculum—too great in some people's opinions—and a decided change in the methods adopted. In general one might almost say that more and more emphasis is being laid upon the question and methods of mental development, and less upon the acquisition of knowledge as the prime factor in modern elementary education. The mental development of the masses of the people is of greater and more permanent value than the mere acquisition of knowledge which may be put to immediate use. If the first be attained the latter is easily realised.

It is, therefore, of great importance to all concerned, in the further education of young people that this development should be borne in mind. Those who may have the idea that these continuation schools will train engineers or moulders or patternmakers as such—as, unfortunately, the earlier methods turned out cheap clerks—will certainly be disappointed. What can be demanded of them is that they should be carried on on such lines as will enable the future workman to have a clearer view of the principles of the methods employed in his work, and to comprehend and enter into the reasons for yhich any particular process is designed.

Steel and its Defects from the User's Point of View.

On the 28th ult., Mr. F. C. A. H. Lantsberry, M.Sc., F.I.C., gave a lecture at the Birmingham Chamber of Commerce before the Association of Drop Forgers and Stampers, on "Steel and its Defects: A Study from the User's Point of View." He pointed out that to get the best out of steel, close co-operation between the steel-maker and the steel-user was necessary. In the past the user had been too prone to lay the blame for all the difficulties connected with steel at the door of the steel-maker and to expect the steel-maker not only to solve the difficulties connected with steel manufacture, but also, with very limited opportunities of study, to supply on demand details of methods calculated to overcome difficulties encountered in use. Machining difficulties were referred to the steel-maker when a slight alteration in the rake of the tools, or a slight variation in the cutting speed, or even a sharpening of the cutters, would have produced the necessary improvement. However, the setting up of scientific investigation departments by large manufacturers would gradually alter this state of affairs, and the user of steel would be in a position to discover the defects of steel from his own point of view and not leave the whole of the work to the steel-maker.

The lecturer went on to assert that there never was a time when so much steel suffering from defects arising from unsoundness and segregation was supplied to users, and the latter were disposed to wonder if steel-makers were exercising that scientific control and care of which the war was supposed to have taught them the value. Delays in delivery were explainable and could be excused, but what possible explanation could be offered of the delivery of a 0.6 per cent. carbon steel to an order calling for dead-mild steel?

The lecturer proceeded to detail various formulæ for calculating the strengths of steel. The general conclusion he arrived at was that the mechanical properties of acid and basic steel showed a difference of only 1 ton per square inch, a difference hardly worth bothering about. In many specifications for constructional purposes, open-hearth steel was definitely called for, but he (the lecturer) held that the superiority of acid over basic steel was not definitely proved, and that given two steels—an acid and a basic of identical composition—the difference in their mechanical properties was not sufficient to be the determining factor in making the choice between them.

The most important consideration from the user's point of view was that the bars or billets supplied for use should have been made from a sound ingot. That meant an ingot not only free from blowholes, but having the constituents of the steel fairly uniformly distributed throughout its mass. Apparently the casting process was the most important operation in the manufacture of steel, for then the initial crystallisation occurred, imparting to the steel a certain primitive structure, which probably could not be eradicated by any thermal process short of re-melting.

The lecturer gave a detailed account of casting processes, and of the special efforts that had been made by pressure, hydraulic and otherwise, to get rid of unsoundness. He claimed that, from the user's point of view, the Robinson process (involving lateral compression) should be regarded with most favour, because of the possibility it presented of the complete removal of the segregation. It was difficult to see how any fluid compression process could *per se* prevent segregation. If any such effect was produced, it must be due to a secondary effect in the way of an increase in the rate of solidification, because of the use of ingot moulds of heavier section. The presence of segregate implied lack of homogeneity, which was the cause of more trouble in the use of steel than the mere presence of relatively small quantities of impurities. Comparatively small quantities of impurities distributed with absolute uniformity would cause less trouble and have less detrimental effect on steel than a smaller quantity distributed heterogeneously. The essential points in the production of sound homogeneous steel were the proper "killing" of the steel by the addition of silicon, manganese, or aluminium to deal with the gases, and the following up of the contractual cavity. From the common-sense point of view there seemed no reason why this could not be done quite effectively by means of the feeder head without resorting to the costly expedients of fluid compression.

Incidentally the lecturer pointed out the danger in the use of aluminium as a "killing" agent because of its liability to become converted into alumina, which gave considerable trouble on account of its highly abrasive properties. Dealing with improper inclusions, the lecturer said it was no uncommon thing to find quantities of nickel-chromium and tungsten in steel supposed to be straight-carbon steel, and he had heard of brittleness in case-hardened objects being attributed to the presence of 0.5 per cent. of nickel in the steel. Other defects were due to cold shuts in the excessive scaling and adherence of foreign matter during re-heating, twisting during rolling operations, and working at too low a temperature. Persistent brittleness was associated with the conditions of initial crystallisation, and difficulties of heat treatment were often due to initial solidification having taken place under wrong conditions.

With regard to the announcement that Mr. J. C. Gould, M.P., has obtained a controlling interest in Richardson, Duck & Company, Limited, and in Blair & Company, Limited. Mr. Gould states the control of both companies will pass eventually to the Gould Steamships and Industrials, Limited.

THE
FOUNDRY TRADE JOURNAL

is Published the first week in each month.

Subscription Terms: 7s. 6d. per annum, post free.
All Subscriptions are payable in advance.

To place the "Journal" within the reach of working Moulders and Pattern-makers, the Proprietors will accept subscriptions, not less than three in number from one shop, at the reduced rate of 5s. per annum, such order to be countersigned by the superintendent or foreman.

All communications to be addressed to the Editor, or to the Publisher, as the case may be, of

The Foundry Trade Journal,
BESSEMER HOUSE, ADELPHI, STRAND,
LONDON, W.C.2.

INSTITUTION OF BRITISH FOUNDRYMEN.

LIST OF SECRETARIES—

General Secretary: Alexander Hayes, 116, Rusthall Avenue, Bedford Park, London, W.4.

Manchester: J. Hogg, 365, Manchester Road, Burnley, Lancs.

Birmingham: H. Field, 12, Bayswater Road, Handsworth.

Sheffield and District: A. Whiteley, 10, Stumperlowe Avenue, Fulwood, Sheffield.

Scottish: J. Macfarlane, 3, Sharrocks Street, Ibrox, Glasgow.

London: A. Willis, Norfolk House, 324, South Lambeth Road, Clapham, S.W.

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Newcastle-on-Tyne: H. A. J. Rang, 2, St. Nicholas Buildings, Newcastle-on-Tyne.

East Midlands: H. Bunting, 17, Marcus Street, Derby.

Coventry: Mr. F. H. N. Lane, Queensberry, 2, Dover Street, Coventry.

Contents.

	PAGE
Rotary Casting Machines	345
Education in Relation to the Foundry Trades	353
Education in Relation to	362
Steel and its Defects from the Users' Point of View	364
Notes and Comments	365
Clyde Steel and Engineering Works, Hamilton	367
Notes on the Properties of Pig-iron	369
Institution of British Foundrymen—	
Sheffield Branch	371
Birmingham Branch	377
Coventry Branch	379
Birmingham Branch	382
New Testing Machines	384
Consumption Figures in the Brass Foundry	386
Trade Talk	387
Personal	388
Deaths	390
Applications for Patents	390
New Companies	392

NOTES AND COMMENTS.

Crystallography of Alpha and Beta Iron.

Writing in the issue of "Chemical and Metallurgical Engineer," dated March 31, Dr. F. Giolitti, the eminent Italian metallurgist, gives a complete classification of the various microscopic appearances of hypo-eutectoid steels, and in particular discusses the origin of the familiar Widmanstätten structure in carbon steels. The original article will be of considerable interest to all iron and steel metallographists.

The origin of the Widmanstätten structure has been studied very minutely by the Russian metallurgist Captain Belaiew. Belaiew has been able to reproduce in pure steels containing about 0.50 per cent. carbon the Widmanstätten structure exactly as found in the natural meteoric irons which almost invariably contain nickel. Incidentally this investigator also drew attention to the similiarity between the equilibrium diagrams of the iron-carbon and iron-nickel alloys. Belaiew considers that the conditions necessary for the obtaining of a perfect Widmanstätten structure in carbon steels are the combination of a long high heat followed by extremely slow cooling. He also considers that this structure depends entirely upon the orientation of the crystalline mass and in steels is independent of their carbon contents.

Dr. Giolitti draws attention to a sample of sheet steel which had formed a portion of a heat treatment muffle and in which, as a result of its exposure to carbonising influences, varied in carbon from 1 per cent. on the inside surface to practically zero at the outside. As a result of prolonged exposure to temperatures well within the Austenite range, full opportunity had been allowed for even slowly moving soluble segregations to equalise their distribution throughout the metal. It was also carefully pointed out that the Austenite crystals were not strictly uniform, as they varied in carbon concentration from the inside edge to the outside edge; but this variation is quite distinct from the initial non-uniformity of the actual individual Austenite crystals caused by the solidification of the sample from the molten state. Giolitti states that the cooling from Ar_3 to Ar_1 was much slower in this case than that of moderate-sized pieces of steel exhibiting the Widmanstätten structure and that required by Belaiew's observations. In fact, this sample which, accepting the whole of this latter worker's hypotheses should have had a "reticulated" structure, had, in fact, a "perfectly developed" Widmanstätten structure.

From a micrographic study of this sample of steel in various states of heat treatment, Giolitti shows that in those areas in which the carbon content is low enough for the ferrite to primarily form as β iron, show a distinctly different structure from the areas in which the whole of the ferrite is directly formed as α iron (in the somewhat higher carbon areas above 0.40 per cent. cc.). In the first case a large portion of the ferrite existed "in rounded grains common to ordinary soft steel," and in the other case the ferrite "existed as needles of striations in concordant groups, an appearance common to Widmanstätten structures."

This observation leads Dr. Giolitti to the assumption that in the case of α iron, this variety has a plate-like habit, while β iron has a granular habit of crystallisation. After citing several confirmatory observations which in themselves are extremely interesting, the author proceeds to give a detailed classification of the structures to be observed based upon this hypothesis.

The original article is worthy of detailed study, and the origin of the various typical structures to be found in mild steels has never been clearly stated. One is apt to become so familiar with these structures as to omit to consider their origin. THE EDITOR.

Foundry Education.

A correspondent in an article dealing with Education in Relation to the Foundry Trades, which appears elsewhere in this issue, calls attention to the provisions of

the new Education Act of 1918. The time is gradually approaching when this Act may be expected to come into operation, and we, along with all far-seeing foundrymen—employers and employés alike—welcome the provisions of this Act as a step in the right direction towards ensuring a higher standard of knowledge and training in our future apprentices.

In so far as the foundry trades are concerned, the question of the correct and systematic training of the apprentices has always been a subject for considerable thought on the part of foundry employers, managers, and foremen. By its very nature the foundry trade does not hold nearly the same attraction for the intelligent youth as does other branches of the engineering trade, and yet the foundry trade calls for a higher degree of skill and individual intelligence than any other section of the industry. At the present time the acute shortage of apprentices in the foundry trades has resulted in a more widespread interest in the educational systems which, along with welfare schemes, are the only methods available of awakening the necessary interest in the trades.

The most important provision of the new Act is the compulsory training for all youths who attain the age of 14 years. This training is to be given during the day time, and it will be the duty of every local education authority to formulate the necessary schemes which shall embrace the formation and maintenance of the classes and schools. Broadly speaking, we are generally in agreement that this scheme is on the right lines, and from the foundry trades point of view we are more immediately concerned with the system of training to be adopted.

Our correspondent presents what to many individuals in the foundry trades may be quite a new idea, and which, briefly summarised, amounts to the fact that actual mental training—that is, training so adapted as to develop the capacity of a youth "for using his brains"—is to be preferred to vocational training. As our correspondent points out, the former scheme is the one which "will enable the future workman to have a clearer view of the principles and methods employed in his work, and to comprehend and enter into the reasons for which any particular process is designed."

In spite of this, the courses of study decided upon in the future continuation schools should bear some relationship to the staple industry of the district in which the school is situated. We presume that the manufacturers will be called into conference with the Education Authorities to assist in drawing up these curricula.

In so far as the foundry trades are concerned, it is to be presumed that the prospect of the continuation school system becoming an accomplished fact in the comparatively near future is already occupying the attention of the various foundries in different districts.

New Catalogues.

We have received from the Sturtevant Engineering Company, Limited, 147, Queen Victoria Street, London, E.C.4, new editions of their Monogram Fan Catalogue No. 1,014 and Steel Plate Fan Catalogue No. 1,052. The senders point out that they will be very pleased to forward copies to any inquirers, and to give any further information that may be desired.

Foundry Education.

The position of students whose course of studies was interrupted by the war, or by special circumstances arising from the war, has been sympathetically considered by the Council of the Institute of Metals. It has been decided to recommend for ballot as Student Members of the Institute candidates for election who, whilst being students of metallurgy, have passed the age limit of 25 years for admission to Student Membership. Students so elected may remain in the category of Student Members up to June 30, 1923, so long as they continue to be students of a recognised school of metallurgy. This concession represents an appreciable financial saving, as a Student Member pays only the guinea entrance fee and guinea subscription of pre-war days. Though in operation for only a few weeks past, the arrangement, we understand, has resulted in Student Membership applications being received at the offices of the Institute, 36, Victoria Street, S.W.1, to a greater number than was the case in the whole of 1919. By a further concession, Members and Students elected at the forthcoming ballot on May 31 will not only have the privilege of membership for thirteen months instead of the usual twelve, but will receive an extra copy of the "Journal of the Institute of Metals," of which important publication volumes to the value of over £1,000 have been sold to non-members during the past twelve months—surely a unique record for a young scientific society.

Books Received.

We have received from the publishers, Messrs. E. and F. N. Spon, Limited, a copy of the second edition of "Stobbs' Wire and Sheet Gauge Tables" (5s. net), by Thomas Stobbs. The tables are compiled to suit the requirements of merchants, manufacturers, and those connected with the wire, sheet, and other metal industries. In view of the increasing use of the metric system in this country, the author has selected the tenths and hundredths of a millimeter as units, giving the equivalent in the decimals at an inch. Imperial Standard and Stub's wire gauges, with decimals, being the two wire gauges mostly in use, dividing the two gauges, 24 G, and under, into gauge and half-gauge, over 24 G, and under, inta gauge and gauge tight, these tables will be most useful, as they show at a glance the equivalents when ordered to the millimeter thickness.

THE SPANISH IRON INDUSTRY.—The Spanish iron industry is in great difficulties owing to the cessation of war orders and the resumption of foreign competition. Since the armistice the following blast furnaces have been blown out: Two at the Mieres works, one at the Duro Felguera works (where the other is working on a reduced scale), two at Nueva Montana, one at Moreda y Gijon, one at the Malaga works, one at the Martinez Rivas works, and two of the five at the Vizcaya blast furnaces. All the mills are, moreover, faced with difficulties arising from the increased prices of ore, the enactment of an eight hours working day, and the continued demands for increased wages. The Government seems disposed to comply with the requests of manufacturers for the re-establishment of the Custom duties on iron and steel which were suspended during the war, but even if the whole internal market were secured, Spain would be unable to consume all the ingots produced by her steelworks.

PROTECTION OF HOISTS.—A detailed and illustrated review of the whole of the factors to be taken into consideration and special forms of apparatus to be used in preventing accidents is issued under the title of "Protection of Hoists" Safety Pamphlet No. 2, published by H.M. Stationery Office. This will be of considerable interest and value to all foundry owners, managers and foremen. The number of hoist accidents reported year after year to the Factory Department indicates that the danger from this class of machinery is not sufficiently realised by either employers or operatives. The object of this pamphlet is to set out briefly and in simple language the chief dangers to be guarded against in the use of hoists of the cage type, such as are generally found in factories and warehouses, and the best methods by which this can be done. More detailed information will be found in the Report by Mr. W. Sydney Smith, H.M. Inspector for Dangerous Trades, on the Construction, Arrangement and Fencing of Hoists and Teagles, published in 1904. Hoist accidents are mainly due to one of three causes, viz.: (1) Failure of the lifting ropes or mechanism; (2) crushes between the cage and door lintels or other projections in the hoist well; (3) falls down the well owing to unfenced condition or inadequate fencing of the doorways. Of these (2) and (3) cause the majority of hoist accidents.

Clyde Steel and Engineering Works, Hamilton.

The works of Messrs. Archibald Baird & Son, Limited, were established over fifty years ago, having been commenced in Glasgow by the late Mr. Archibald Baird and his son, the late Mr. Matthew B. Baird, for the manufacture of crucible steel castings. In 1887 new works were laid down in Hamilton, and engineering was added to the foundry business. Owing to the increased demand for heavier steel castings the crucible furnaces were dismantled in 1895, and a bottom-blown Bessemer plant installed. This plant, with minor modifications, did the foundry melting for a number of years.

After disposing of their Cairnhill Iron and Steel Works, where they manufactured iron and steel bars and sections, the company decided to entirely rebuild their Hamilton Works, and commenced operations in 1912. The work was only partly done when war broke out, and had to be suspended. The whole scheme has now been completed, and was carried out without production being interfered with in the slightest degree. All old plant was ruthlessly scrapped, and the most modern and efficient plant and tools installed.

FIG. 1.—CASTING BAY : CLYDE WORKS.

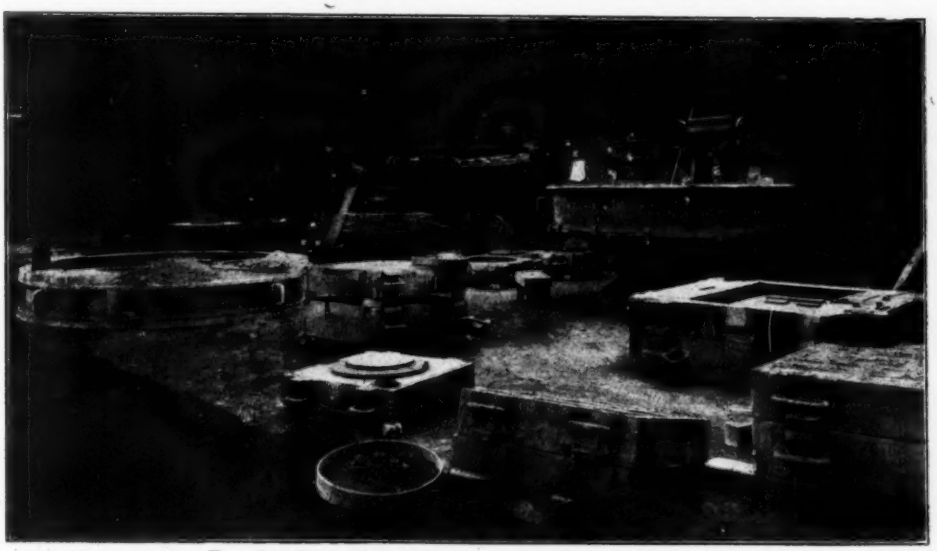


FIG. 2.—GEAR MOULDING MACHINES : CLYDE WORKS.

The main works consist of four parallel bays with all-glass roofs, and of exceptional height, the foundry

being placed between the engineeering shop and the dressing shop, whilst beyond the latter is the loading bay, the sidings from which join up with the North British Railway. The foundry bay is over 300 ft. long with a span of 48 ft., and is served by two overhead electric cranes. The Tropenas plant is in a central position and adjoining the power house. The cupola plant is adjacent, and is served by an electric hoist; the charging platform, as also the storage yard for pig-iron and coke, etc., are all under cover.

In addition to the furnace controls, the power house contains two Thwaites blowers (each direct-driven by 120-h.p. Bruce-Peebles motors), two Keith-Blackman direct-driven motor fans and a Mawdesley converter of the drying stoves, and are heated from the same gas producer as the stoves. The sand-mixing plant is placed in an extension of the core shop.

The dressing shop is served by two overhead electric cranes, one of which runs directly over railway wagons in the sidings. Here there is an oxy-acetylene plant and cold saws for removing risers; a tumbling barrel, two sets of Norton emery buffs, and electric welding plant. At one end there is a series of smiths' fires served by two steam hammers, and at the other end two gas-fired annealing furnaces.

The engineering shop is served by an overhead electric crane. In addition to the usual complement of small tools, the equipment includes modern tools sup-

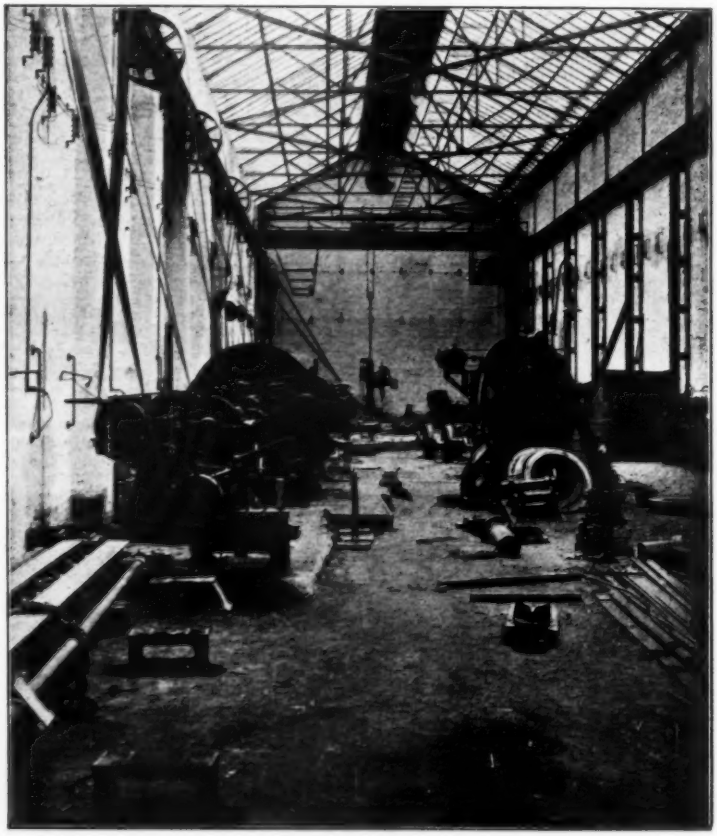


FIG. 3.—ENGINEERING SHOP.

set for electric welding. Power is distributed here from a large switchboard to all parts of the works, and is supplied by the Burgh of Hamilton Electricity Supply Company.

Between the foundry and the dressing shop bay a new sand-blast plant has just been laid down. It consists of two Tilghman's sand-blast chambers, the air compressor having a capacity of 600 cub. ft. per min., and being driven by a Westinghouse 80-h.p. motor, and the exhaust fan by a Westinghouse 35-h.p. motor, the sets being housed in a dust-proof brick building. Conveniently situated in the foundry is a battery of gas-fired drying stoves.

The core shop is contained in a lean-to off the foundry, and the core stoves—which consist of six nests of four ovens high—extend along the side of one

plied, among others, by Messrs. John Lang & Sons, Limited (Johnstone); William Asquith, Ltd. (Halifax); J. Butler & Company (Halifax); C. Redman & Sons (Halifax); Ward, Haggas & Smith (Keighley); James Archdale & Company, Limited (Birmingham); and the Cincinnati Shaper Company (Ohio, U.S.A.). The engineering shop is driven by motors, and power is transmitted through shafting running in roller bearings.

The pattern shop is situated conveniently to the foundry, and contains band and circular saws, lathe, wood grinders, etc.

The laboratory adjoins the works stores and head offices, and is well equipped for testing raw and finished materials.

Notes on the Properties of Pig-Iron.

It is generally admitted by both blast-furnacemen and foundrymen alike that there is considerable differences in the general physical properties of pig-iron produced from different blast furnaces under different conditions of working, even though possessing in the main identical chemical composition. It is also claimed that castings made from pig-irons of various origin, even though of identical chemical composition, show an appreciable variation in physical properties according to the origin of the brands constituting the mixture. Exactly what this difference in quality is has never been strictly defined, nor is the writer aware of any definite experiments having been published showing the extent of the variation in results that might be expected from any different pig-irons of the same composition. In many makers' catalogues statements are to be found that certain irons give superior mechanical properties, superior resistance to wear and increased soundness in the finished castings. Exactly what such statements are based upon is often extremely difficult to ascertain, and in a like manner it has been found very difficult to propound a theory giving a detailed explanation of the reason why such a difference in general physical properties should exist.

The use of cold-blast irons, charcoal irons and special cylinder irons in foundry mixtures is stated to confer exceptional physical properties on the resulting castings. Closely allied to the same phenomena is the use of steel scrap in foundry mixtures. It is very frequently claimed that castings made in so-called semi-steel mixtures have considerably improved physical properties over castings of the same chemical composition made from mixtures not containing steel. In the first place it is undoubtedly true that two or more irons, having practically the same chemical composition, but different mechanical strengths, can be obtained from the same or different foundries, but as a general rule the difference in tensile strength is very small. The factors which will have to be taken into consideration in comparing the strength and other physical properties of cast irons of the same chemical composition are:—(1) Casting temperature, (2) rate of cooling, (3) size of test-piece, (4) method of casting the test-piece, (5) method of machining and finishing the test-piece, (6) method of breaking the test-piece, and possibly (7) detail of the melting of the iron.

Before the strength of two or more irons of the same chemical composition can be compared, the whole of these factors must be strictly constant or their relations must be accurately known. The difficulty of attributing a variation of a magnitude of one or two tons to the character of the pig-iron used in the mixture will be at once apparent. These same factors have to be taken into consideration in the case of all the other physical properties to a greater or lesser ex-

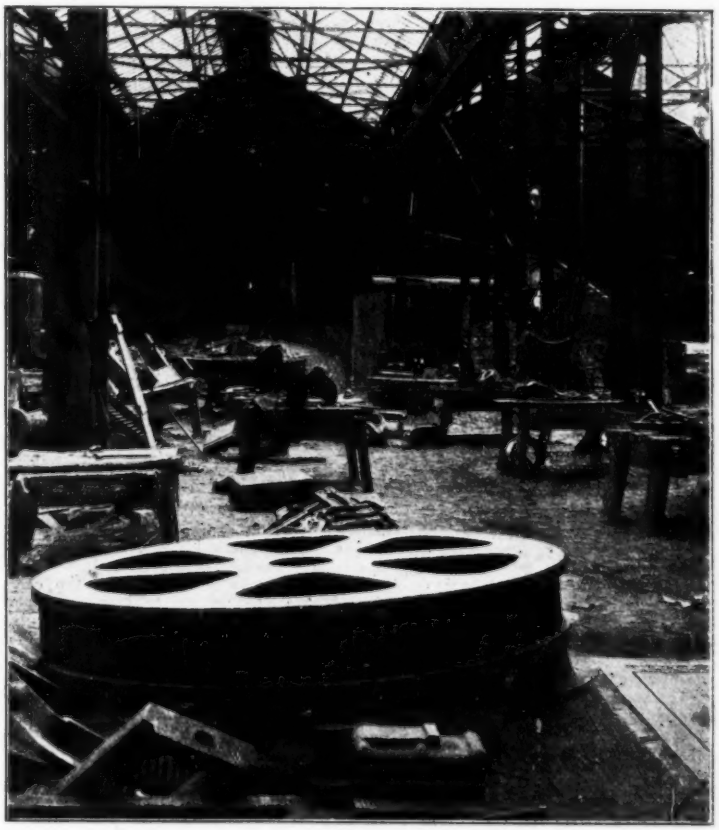


FIG. 4.—DRESSING SHOP.

tent. For example the method of carrying out the transverse bending and breaking test in this country is extremely crude as is also the measurement of the deflection in the same test. As would be expected, the irregularity met with in these tests is considerably more pronounced than in the case of the tensile test, and the irregularity met with in the measurement of the deflection varies to a still greater degree. There is need of a very accurate and authoritative research into the physical properties of cast-iron with a view to ascertaining to what extent the character of the pig-iron does influence them without in any way influencing the chemical constitution. Another and possibly more important aspect of the same question is the influence of the brand of the pig iron used in the foundry mixture on the chemical composition of the final casting with an accompanying modification of the physical properties. Abundance of evidence can be produced to show the influence of the brand of the pig-iron on the condition of the carbon content without any material change in the remainder of the constituents. The theories which have been put forward from time to time purporting to explain the phenomena in question are interesting, but no definite support has been given to any of them. A brief examination, however, will be sufficient to indicate the origin of the belief that the difference in properties is to be attributed to the temperature of production of the pig-iron. In the case of Swedish and charcoal pigs the exceptional purity of the material should also be taken into account.

A widely prevalent belief exists in this country that the difference in physical properties is due to the presence of some element or elements hitherto undetected in the ordinary routine chemical analysis. If dissolved gases or occluded gases are included under this heading, there is no doubt some truth in the belief, but apart from this it is extremely unlikely that the combined influence of the minute traces of the additional elements found in pig-iron after exhaustive analysis is of sufficient magnitude to exert any influence on the physical properties. In making this statement it is, of course, assumed that the additional elements either do not, or are not, present in sufficient quantities to modify the condition of the carbon. Obviously, if this were the case the reason for the difference in the properties would be at once apparent. In the United States the belief has been put forward that the difference in the physical properties is to be attributed to the presence of oxygen in the material. This theory is the result of a series of investigations of the late J. E. Johnson, jun., who sought to produce the equivalent of cold-blast charcoal iron by blowing air through molten coke-iron low in silicon and adding the necessary silicon after the operation. Johnson sought to show that the influence of oxygen was exerted through its influence on the condition of the graphite. It was claimed that the presence of oxygen was coincident with a peculiar "nodularising" or balling up of the graphite which otherwise exists in the form of plates. The former arrangement is typical of cold-blast charcoal irons. A certain amount of support is given to this theory by Professor Howe in his recent book. "Metallurgy of Steel and Cast-iron." A photograph is there given showing the characteristic graphite arrangement in Johnson's oxygenised pig-iron.

It has been pointed out in this country, notably by Professor Turner, and also by certain Swedish workers, that the properties of cold-blast charcoal irons are rather due to the absence than the presence of oxygen.

It cannot yet be considered to be definitely proved that dissolved or occluded gases exert any influence on the properties of pig-iron, and further it is extremely difficult to understand why oxygen should exert so profound an influence in view of the known presence of much larger quantities of other gases, e.g., carbon monoxide and hydrogen. Moissan has shown that oxygen was responsible for some influence on carbon, causing it to swell and increase in volume, a phenomenon which he described as "intumescence." This phenomenon would not be expected in any way to tend towards an improvement in the mechanical properties of pig-iron. In fact, it has been used by certain other writers to explain the falling off in tensile strength of grey cast-iron when subjected to comparatively high temperature conditions. In spite of our almost entire lack of knowledge regarding the influence of dissolved or occluded gases on the properties of cast-iron there appears every possibility that their influence is most profound. Some justification for this belief is to be found in our knowledge of the influence of gases on the mechanical properties of certain other alloys such as gun metal and aluminium. (Carpenter and Elam J., Inst. Met., 1918.)

Some very interesting hypotheses have been put forward by Mr. J. E. Fletcher, regarding the influence of dissolved gases on the structural arrangement of the constituents on the solidification of molten cast-iron. He sought to prove that the structural distribution of cast-iron on solidification is largely dependent on the course taken by the dissolved gases on being liberated at the solidification point.

Further hypotheses have been advanced by other writers in which it is assumed that the difference in quality is due to the modification in the character of the free carbon. In the first place, it may be pointed out that this phenomenon, if fully established, may not altogether be unconnected with that of dissolved gases. An examination of the theories put forward in this connection shows that they fall under two heads: (1) Those theories in which it is sought to explain that the character of the graphite is different according to the different temperature of the production of the pig-iron in the blast-furnace. (2) Those theories in which it is sought to explain that the ratio of the combined to free carbon, other conditions being equal, depends upon the temperature of production of the pig-iron.

With regard to (1), apart from the evidence based upon the visual examination of the fractures of different varieties of pig-iron, there is nothing to justify the assumption of the existence of more than one modification of the free carbon separating at different temperatures.

With regard to (2), it has long been held that the explanation of the presence of free carbon in low-silicon pig-irons is largely a result of the temperature at which the iron was produced.

Exactly as in the case of the occluded gases, it is difficult to appreciate how any peculiarity in the original pig-iron can survive the subsequent remelting in the foundry cupola for the production of castings. Mr. E. Adamson has advanced an hypothesis, which has also been made by Mr. E. L. Rhead, that a portion of the graphite dissolves only with difficulty on re-melting the pig-iron in the foundry cupola. One also concludes from Mr. Adamson's remarks that the extent of the re-solution of the graphite on re-melting depends upon the nature of the graphite, which in its turn possibly depends upon the temperature of the pig-iron production. It should, however, be a comparatively easy matter to quench samples of cast-iron (hypo-eutectic) from the molten state, and to show the existence of undissolved free carbon. Such an experiment as this would conclusively prove the assumption or otherwise of the failure of a portion of the free carbon to redissolve. From other considerations it appears extremely unlikely that this theory is tenable.

In the production of castings under a high rotary speed, no evidence has yet been obtained of a separation of the free undissolved carbon on the inner surface of the castings. If a portion of the free carbon were to remain undissolved in the molten iron, it would, on account of its low specific gravity, be most certainly segregated to the centre of the casting under the influence of the centrifugal force due to the high speed of rotation. The fact that the graphite is evenly distributed in castings made under these rotary processes is positive proof that the whole of the graphite is in perfect solution in the molten iron, and that the formation of the graphite takes place shortly after solidification.

Institution of British Foundrymen.

SHEFFIELD BRANCH.

Annual Dinner.

The annual dinner of the Sheffield Branch was held at the Grand Hotel, Sheffield, on March 5. The company numbered upwards of 100, and was also representative. The chair was occupied by Dr. W. H. Hatfield (Branch President), who was supported by the Lord Mayor of Sheffield (Councillor S. Roberts), Mr. John Little (President of the Institution), Councillor T. H. Firth (Past President), Mr. H. L. Reason (President of the Birmingham Branch), Mr. William Clark (Senior Warden of the Cutlers' Company), Mr. Peter Brown (President of the Sheffield Junior Engineers), Mr. F. C. Fairholme, Mr. J. R. Hyde (Vice-President of the Sheffield Branch), Professor W. G. Fearnsides (Professor of Geology at the University of Sheffield), Mr. J. H. S. Dickenson (President of the Sheffield Association of Metallurgists and Metallurgical Chemists), Mr. J. M. Allan, Mr. T. W. Willis, Mr. F. Best, Captain Rundle, R.N., D.S.O., Dr. A. McWilliam, C.B.E., Mr. A. J. Grant, and others.

After the loyal toasts,

Mr. John Little proposed "The City and Commerce of Sheffield." He said that there were many imitations of Sheffield amongst their friends across the water. He believed the city had quite half-a-dozen namesakes, and in the old, pre-war days Germany, he supposed, created them to suit her purpose, but when the world spoke of Sheffield, it thought of the biggest city in broad-acred Yorkshire, the birthplace of the finest metallurgists the world had ever produced, and the most prolific arsenal of all time. "Sheffield" stood for development every time. In its steel manufacture it had developed from the "rule-of-thumb" days—wonderful as they were—to the highest degree of scientific production. The quality and variety of Sheffield steel were constantly developing. There was no standard too high—no finality in research work. The development of Sheffield's great armament firms in the comparatively brief span of half a century was an absolute romance of industry, and equally remarkable was the city's contribution to the world's requirements in the way of tools and implements and machinery for peaceful industries. What Sheffield did towards bringing about the Allies' stupendous victory in the world war would be recounted for centuries to come, and few great industrial centres had developed a reconstructive power so rapidly as that now evidenced on every hand within the borders of the city of steel. Sheffield emerged from the war period stronger and bigger and more wonderful in resourcefulness and enterprise than ever. The foundations of her industries had been broadened and buttressed, and new valuable markets secured overseas. Already there had been greater developments since the signing of the Armistice than would have been considered possible in a whole generation in the old days, but he firmly believed that what they had already seen was the beginning of Sheffield's development as an industrial city. Those of them who lived long enough were destined to see far greater things. And in all these developments the foundries of Sheffield would have a large place, and an increasingly important one. They were in the van of all industrial and constructive progress. Only on one point had he any misgivings as to Sheffield's industrial future. Would Labour play the game, or would it listen to the poisonous insinuations of anarchic suggestion? Would it be amenable to reason, or would it be high-handed?

The Lord Mayor, in reply, humorously referred to the value of technical societies, and said that without the science and the energy which they were putting in the commerce of Sheffield would not be as prosperous as it was, and without the commerce of Sheffield there was no need for any city at all. He wished the Branch every success.

Mr. William Clark also replied.

Mr. Peter Brown proposed "The Visitors."

Mr. F. C. Fairholme, in reply, commended the work of the Institution of British Foundrymen, particularly its activities which afforded a means for the members to discuss the practical difficulties of their daily routine, and to assist each other in elucidating those difficulties which, in a trade like theirs, were of peculiar importance.

Mr. H. L. Reason, who further replied, said that as an Institution they were very proud of the Sheffield Branch, which had given them three Presidents of the parent body. First they had Dr. Longmuir. Then they had Mr. T. H. Firth, whom they were delighted to see there that night after his recent illness, and to whom they would always feel indebted for the work he had done. As an Institution they had done their best, from an educational standpoint, to improve their craft. They were seriously in want of funds, and, seeing that they realised the position and were willing to take their part in the industry, it was time that the employers did their part and assisted to put the Institution on a good financial basis. As most of them knew, the Government had voted a million sterling towards industrial research, but up to the present the iron and steel industries of the country did not seem to have taken any advantage of it. He quite appreciated that in a very rich city like Sheffield, with their research laboratories under such able leadership as that of Dr. Hatfield, they did not really want Government assistance, but, speaking for the foundry trades in general, they would like to see a Research Association formed for the grey and malleable iron industries. They felt that they were to some extent groping in the dark, and that if they were to keep pace with foreign countries they must take as much advantage of scientific work as possible.

Mr. J. R. Hyde proposed "Kindred Associations." He said their object was to teach people to do better, and if instruction was to be given successfully it had to be put in a very palatable and presentable way. Some of the lectures and discussions which they got at those Associations were of a tonic nature, but they were nicely wrapped up, and what they learnt could be taken to the works and introduced without a lot of fuss or without any upset of their conservative Sheffield natures. If they could introduce beneficial improvements without too much dislocation of the ordinary routine, some good would accrue, so that the work of Associations similar to theirs was of lasting value.

Professor Fearnsides, in reply, said he thought all who were in foundries recognised that their wants had something to do with physics, and something to do with chemistry, something also to do with engineering, while metallurgy was certainly one of the associated institutions from which they must draw as from a fund of accumulated knowledge. It had seemed to him, in going in and out

of foundries and among foundrymen, that not always did the British foundrymen draw from the available sources of knowledge which they ought to draw from, and which were already existing in foundries. No doubt the Institution contained among its membership people who were interested in "running the show," and people who were interested in the technics of the show. He wondered if they always recognised that they had in their works a great deal of accumulated knowledge, which had not been codified, and which might be the means of tremendous advance if it could be brought to those people whose business it was to teach chemistry and physics at the Universities and to understand what they taught. The foreman who knew how to judge sand in his hand, and who judged it right nearly every time, generally had some sort of knowledge of materials which no scientific man seemed to have been able to get a grip of at all. He thought one of the things that was wanted more than anything else was the interpretation of that which was common practice amongst the best of the workmen in the foundries. It would be to the advantage of all concerned if, among the associated institutions, they had as a part of their organisation a great deal more of those skilled foundrymen.

Mr. J. H. S. Dickenson, responding for the Sheffield Association of Metallurgists and Metallurgical Chemists, which had only been in active operation for about two years, and which owed so much to the initiative and vigour of Dr. Hatfield, said that amongst the consequences of the war there were a few which he thought had been to their advantage. He hesitated to mention one of them, which was the committee habit that sprang up during the war—the formation of various technical committees by the Air Board and other Government Departments to discuss technical matters. They did not want those committees any longer, but he thought they had been useful in that they had taught many people that they did gain by exchanging ideas. He thought that, partly as a consequence of these committees, and partly as a separate simultaneous movement, probably operating from the same reasons, there had been during the last year or two a tendency for the formation of new societies, scientific and quasi-scientific, and technical, to discuss all sorts of human activity. Besides these, societies had been formed which were frankly run for economic objects, and with those they were not directly connected. Knowledge which was not properly distributed, not directed into channels where it could be made full use of for the purposes of mankind, was of little value. The man who, having a little information which might perhaps be of some use to him but which more often was of no use at all, simply locked it away, did not communicate it, but kept it tied up in his own breast, was dealing with a valuable thing in much the same way that a miser dealt with his hoard of coins—he got no interest on it. It was found, in fact, that technical discussions resulted in a general increase of knowledge, and that few who took part in them could ever give away more than in the long run they learnt. In securing that useful distribution of knowledge the technical and scientific societies had their principal function. It was the recognition of this necessity that led to the formation of the Royal Society, and in later times to the foundation of many other scientific institutions. The necessity for them had been more than ever brought home during the war, and not less in Sheffield than in other places. He believed there were about three or four technical societies in Sheffield before the war, whereas there were now something like 17. The file makers, cutlery makers, and so on, had found it necessary to draw together and discuss the details of their work.

Mr. J. M. Allan proposed "The Institution of British Foundrymen." He said the Institution was a branch of the general engineering section of the country. It could not exist by itself, but must exist in connection and in association with other bodies. They were all working to one end. In this country, and probably not in this country alone, from the start of any industry the practical side had come first. As it had advanced men had found difficulties, and other men had come forward and had reduced experience to a scientific basis. They had pure science, and then they had what he considered the workshop science, consisting of the codified results of the experience gained in the workshops; and unless pure science could be brought to the level where it would be used in actual practice in the workshops, then it was of comparatively little value. What was desired was to make use of the combined experience for the general good. He thought firms in this country were so occupied in producing work that they did not feel the necessity of the codification and general construction that was recognised abroad. But the times changed. The introduction of high-speed steel wrought a very great change in this country. It lead to an immense development in machine tools automatic and semi-automatic, and at one period the markets of this country were fairly well flooded with American productions. One section which he thought was immune was that of heavy machine tools. The home of that trade was in this country, and it remained here, and our products were not challenged to any great extent by either America or Germany. But small machine tools did flood our market. Well, that set our manufacturers to think, and compelled them to act.

Dr. Hatfield, replying to the toast, said that in the present condition of industry one thing which they could all do was to get back to Ruskin's idea of work. Ruskin, in examining the old cathedrals and churches of Europe, came to the conclusion that every stonemason who worked upon them was engaged in a labour of love. If the whole of the employees in the foundry would go back a little towards that view, of making labour one of the chief ideas in life, he was sure that much of the present economic difficulty would immediately disappear. The scientific man's attitude of mind was super-critical—all along examining the state of things that was, in the hope of finding out that which was not as it should be or that which could be improved, with an idea to re-mould it nearer to the heart's desire. Fortunately, there were staid and wise business men and captains of industry—others, who sat on the safety-valve and rather objected to the smashing process, but at the same time they were anxious for all the suggestions that could be made in the direction which he had indicated. Mr. Reason had also spoken of research, and the need of Research Associations. Now, he (Dr. Hatfield) was going to speak quite bluntly to Mr. Reason, and through him, he hoped, to the foundry trade of this country. The foundry trade needed all the research and investigation that could be done for it, but more than that it needed to take an interest in the work which had been

done. (Hear, hear.) Before the trade formed a Research Association they should institute an inquiry into the researches and the books which were available.

Factors Contributing to Soundness in Castings.

Before the Sheffield Branch of the Institution, on March 3, Dr. F. Rogers, D.Eng., B.A., M.Sc., read a Paper on "Factors Contributing to Soundness in Castings." Dr. W. H. Hatfield presided.

Dr. Rogers said that, coming among practical foundrymen, he first wanted to destroy any impression either that he was going to expound to them any revolutionary invention in casting processes or that he was going to clog them with a lot of raw scientific dust or unapplied science. What he would endeavour to do was to stimulate that live, restless spirit of inquisitiveness into the "wherefore" of every possible feature of the processes they handled. In industrial processes the type of mind which was very observant, although rarely taking advantage of means of accurate measurement, had long existed, and, indeed, was until latterly the predominating type. Upon consideration it would soon be realised that even that type used such convenient means of measurement as were available. At one time even to weigh the components of a foundry charge was ultra-scientific, for scales were uncommon, the strictly correct proportions of materials were unknown, the raw materials themselves were not strictly consistent, and possibly there would be a big factor of shamefacedness on the first introduction of weighing into any foundry of the olden days.

The acute proprietor or manager would, however, soon realise that by such means of measurement alone could be recorded (mentally or otherwise) what he had done, and reproduce good results. He came back, therefore, to the phrase "keen observer"; he it was who had been able, as it were, to make mental records or measurements of all he did, and apply them to all further work. He had acute physical sensitiveness, therefore, in those respects which concerned what they might call the technical side of his work. His method was a very quick one, and hence often scored in ways in which the scientific method—like art—was likely to be longer than life itself. His method was one which did not lend itself to the recording of data or results. It was without a means of self-expression other than in further manufactures by the chosen processes; it did not lend itself to transmission to others nor to a discussion such as might lead to a common fund of knowledge from which great progressive deductions might be drawn.

The great gifts, however, of a physical sensitiveness and the ability to utilise them were not given to all who might wish to enter into the business. But to-day we had still undoubtedly many able workmen, managers and foremen whose instinct led them mainly to operate on those principles. Since the scientific study of chemistry, metallurgy, physics and engineering had so tremendously developed during the last century, it became inevitable that not only should the foundry processes become objects of investigation for the chemist and the others, but also that the founder should look into, first, the results, and, second, the methods of chemists, etc., for information which might apply in his own work. He even brought in chemists and others to aid him, if possible, in developing his processes. In some cases he actually became more or less a chemist, metallurgist, etc., himself, and in others chemists and metallurgists were actually placed in charge as founders. He was dealing with this point at some length because it was now so much easier to realise the relative outlook of the two types of mind on foundry matters in particular. The chemist or metallurgist might lack that special physical sensitiveness and other qualities which enabled the so-called "born" practical founder to see to the end of his problem, stage by stage, without any measurement or laboratory work. On the other hand, he had a road of practically royal certainty, even though it be of Alpine difficulty, to the solution of the problem of improving present methods or evolving new ones. If he were further endowed with the gift of physical sensitiveness and the ability to utilise it, combining, therefore, scientific method with practical gumption, the result was certain to be highly favourable. It was possible that in some instances the chemist or metallurgist might be a machine instead of being gifted and sensitive to physical phenomena.

In foundry business, perhaps more than any other, one learnt most from faults and failures. The reason for this, as he saw it, might be interesting: it was that Tubal Cain could not, in the nature of things, have sat down and worked out all our problems theoretically beforehand, as he might much more conceivably have done for engineer designers or electrical engineers. Moulding, the pivot of all foundry work, did not at first obviously lend itself to mathematical treatment. In moulding arose, undoubtedly the great majority of defects in castings. Many and varied were the causes of defects which could be traced to errors in moulding; they would consider some of them in due course.

Next in importance as source of troubles was the metal itself. If casting might be regarded separately—the actual pouring of the metal and filling of the mould—this formed a third important source of defects; and fourthly, they had the design of the casting. He had placed them in the relative order of their importance rather than the logical order in which they occurred. In fact, they almost occurred in the opposite order in practice. Design happened first if it happened at all. In regard to design, it commonly had to be accepted that the founder did not get much of a say in the matter. This was a great pity, and was really mainly due to conceit on the part of the individual engineers and designers, who would not bring the founder into the conference—at first. Undoubtedly some of the cleverest casting had been essentially founders' rather than engineers' ideas, as, for example, probably, monobloc water-cooled cylinders. He thought it was practically safe to say that the wonderful casting of the internal combustion engine was a founder's idea rather than an engineer's idea. It was absolutely a question for the founder and the moulder above all things. He took, again, the example of the air-cooled motor to illustrate the tendency to thin sections. In certain branches of engineering there was at one time a sort of rule in the drawing office—he was referring more particularly to steam engineering—to the effect of "nothing less than half-inch." Of course, that was not adhered to generally. The mere existence of that in important drawing offices showed how those thin

sections such as were absolutely commonly required to-day would have been looked at in the past as practically impossible.

It would hardly be in place to go fully into that side of the subject at the moment, but founders know that, speaking generally, the design should be such that the need of chaplets was minimised; that difficult cores, however successful technically, were expensive; and that with certain designs the problem of feeding certain parts demanded special attention in the pattern-making or moulding.

The lecturer then proceeded to deal with a number of lantern slides, some sketches and some photo-micrographs. The first illustration showed how, in all work, single or complicated, the designer might do worse than co-operate with the founder. Dealing with contractions and cavities, the lecturer said there were various possibilities: the top might freeze first because it was a thinner section, while the bottom would freeze last. They always got contraction, and that contraction was very liable to lead to cavities. The moulder had to deal with forms which did not permit of the most favourable positions being taken for casting. It might not be possible to cast them in an inverted position because they were parts of castings. Some forms were liable to have cavities in two places. One part might even solidify before another, due to irregular density of packing of the sand and irregular dryness or wetness of the sand. The moulder would naturally try to think out forms which tended to feed themselves, so as to prevent the formation of cavity. He was attempting to deal with the subject from the point of view of design rather than moulding proper.

The next slide referred to the location of the runner. This was a case in which there was a cylindrical part being cast, and there were three places for the runner. The hot metal poured first over the core, which might do a lot of damage. The casting might be run in a variety of ways, as with the axis of the cylinder included. He knew those things were absolutely examples to his audience, but he hoped they would say more than he had done about it.

There was also the question of the choice of suitable metal. This was largely affected by considerations other than that of founding. The founder did, or should, know a good deal about metal.

In connection with moulding proper, the number of factors was really vast, and he willingly granted that all that could be classed in moulding was really the pivot of founding. Founding was moulding. The great majority of troubles could be traced to something in the moulding. In regard to the choice of moulding sand—he used sand as a general term—they had an almost infinite range of choice. It depended greatly, of course, upon the metal they were going to cast—according to whether it was steel, iron, brass and so on—the form of casting, the relative degree of chill desired or permitted, and such other factors as the sands available locally. It was not practically desirable to have to import one's sand from six thousand miles away, although one would not mind doing that in the case of the ore of an expensive alloy. There were, besides, a lot of physical characteristics such as the fineness of the sand. The most important factors, on which much still remained to be done, were those involved under the heads of refractoriness and bond. They were very important in steel casting, more so than in iron casting, where the temperatures were not so high. The bond in sand was its ability to form a mould which would stand up to its work without being unduly hard. Probably in the majority of sands this was due to a property in the nature of clay; it was at least a near relative to it. There were other properties which contributed to bond. He would consider the clay property for a moment. Clay, previous to burning, appeared to be something which might be represented scientifically by a very long name—colloidal hydrated alumino-silicic acid. When a mould had been used, the parts of the sand which were heated by contact with the metal largely lost the colloidal property. They might, it was true, become burnt to a hard condition. That property of clay by which they could work it and make it a sort of tough substance was, in his opinion, partly connected with the colloidal property. That colloidal property might be simply explained as a tendency to the aggregation of a large number of molecules. Typical colloids in chemistry were such substances as glue and gum when they were wetted. Oils and most of those things which formed thick liquids were colloids. If they took flour and water and mixed them to a paste in the familiar way, instead of having the comparatively simple molecule of flour and water separately they had thousands of molecules of flour and thousands of molecules of water combined into aggregates. He thought the analogy was easily seen when they came to clay, which could be moulded into form and would more or less retain form. In moulding sand they had a certain amount of that clay property—only a small amount. They could very easily work up a form with sharp edges which would stand up whilst the sand was damp, and when dry it would also stand up and not fall to powder. That, he might say, was due to the colloidal mechanism in the case of clay or sand. They always made up their sand with water, which accounted for the term "hydrated." If they took it up to boiling point they drove out much of the water. There still remained some water, which was loosely chemically combined with the sand. The typical clay—china clay or fire clay—consisted of alumina and silica. The mere fact that he used the word "acid" must be regarded as comparative, chemically. It was a weakly acid substance. This was rather a physical than a chemical explanation of the constitution of clay, but it was extremely important in the problem of the regeneration of moulding sands.

Under present-day conditions it was probably becoming a more important problem economically than the question of defects. The problem amounted to that of restoring the colloidal property which had been destroyed or exchanged for bond by the heating of the sand in use. He was not aware that this could at present be commercially accomplished, and therefore methods of regeneration frequently followed the principle of the addition of a small proportion of material of binding properties—usually, therefore, of the nature of clay—upon which the main bulk of used sand acted as a diluent. Quite a low degree of binding properties was for many purposes sufficient. In instances where it was desired to use specially highly refractory sand, *e.g.*, silica sand, which had no binding property at all, moulding could be accomplished with little or even no mineral addition, by the use of binding agents which passed off as vapour under the heat of casting, and which therefore did not lower the refractoriness of the sand in the way clay or the mineral additions would do. If they wanted to

make a pure silica sand core, they could use something which actually burned off and simply volatilised as smoke during the casting. If they simply used pure silica sand with no refractory binding agent, they had to rely at high temperature upon a kind of cohesion in the sand called sintering. That sintering action must not be carried too far. If they got too much of that action they got a very hard material which might cling to the casting and might lead to fracture during cooling or fettling. They might also get scabbing of the casting. It was a general nuisance in founding.

Sometimes there even occurred a fusion of one of the components of the sand, and they formed thereby something like a hard slag, and difficulty arose in getting rid of it.

The question of green sand moulds versus dry sand moulds that had been discussed to a tremendous extent was familiar to at least all iron foundry men. He thought the matter was too indefinable and, in the cases of green sand and dry sand as they were related to defects, too much on the border line. It was best in the case of repetition castings to settle the matter by actual experience. Such matters as the necessary head of metal in order to give sound castings were also much better settled in accordance with the practical conditions, and it had been touched upon in reference to the prevention of cavity. The actual amount depended upon the form of the casting. The important feature about those things—the head requisite and the risers—was that it was essential to leave them in the hands of the founders and moulders, and it was up to them to settle the matter in accordance with experience upon particular jobs. Unfortunately, the great majority of the foundries did an enormous variety of work, and that was the seat of an enormous number of troubles. They were not sufficiently specialised. The dryness of moulds and facings and washes which were most suitable were all questions which were best dealt with in the individual case.

As regards washes and mould facings he would make one general remark: it was his experience that those which tended to make free water or free hydrogen when the hot metal came into contact with them were generally worst. He said free hydrogen, but they would doubt whether it was possible to get free hydrogen. He thought it was. Blowholes in the metal were often referred to the metal itself, but it was not always so. Sometimes it was due to unsuitable mould dressing. Those washes which deposited a form of carbon were generally best. If they had carbon there in a pure form—he did not mean tar, but carbon or graphite—they had something which at least was not likely to do much harm. With most of the metals in contact with it—it scarcely mattered whether it was steel, iron or brass—they did not get a reaction which led to gas, and it was gas of which they had to be afraid.

Certain refractory inert powders, such as lime, might give good results in certain cases; they had to be properly or suitably bound to the sand. If they got those refractory powders detached from the surface of the mould they were always certain to get trouble. The chances of carbon doing any harm were, say, half of what they would have with refractory powders.

Passing from the section of moulding, the lecturer remarked that in the application of science probably more progress had been made in recent years under the head of metals than in any other direction in foundry practice. The slide which he presented was intended to show that they could have dirt arising either from the metal or the mould. Such inclusions of dirt or slag or flux needed, therefore, to be investigated, and they had devoted a great amount of time to the study of such inclusions, so that they could define them and thus trace the trouble to its source. The following slides would show something of the methods of investigation.

The slide which followed showed a rather dirty patch inside the metal. The magnification was 500 diameters, so that it represented a portion which was less than one-hundredth of an inch across. In a steel casting the inclusions were silicate of manganese and pure silica or sand. Another sample contained pure slag. Besides those two types of defects there were blowholes and dirt, and an enormous amount of trouble came from having the metal cast at unsuitable temperatures. It might lead to shot and general brittleness. If the metal was too hot, they might get the casting weak, brittle, and the fracture open and very crystalline in appearance. If they examined the fractures in many metals they would find that the crystalline appearance was something like a tree in form. The metal consisted of a mass of such crystals, and they would not be able, generally speaking, to identify them in the form in which they were shown in the photomicrograph, but sometimes they ran so big as to be visible to the naked eye.

The decturer demonstrated on the screen the structure of typical cast iron, showing the four constituents—graphite, ferrite, pearlite and the phosphide eutectic. Though the total impurities in the iron were only about 4 per cent., and carbon had by far the larger share, yet they would see that the phosphorus constituent occupied a large and important position. The phosphorus contained in the sample was less than 1 per cent. Where there was pure carbon they would see that its influence also was out of proportion to its percentage. The sample contained about 3 per cent. of carbon, which was represented by the plates of graphite almost extending across the piece. They had no strength whatever. The carbon was not as strong as lead pencil, being a more powdery kind of graphite.

Taking the phosphorus constituent, they would see that it very nearly formed continuous envelopes. Since that phosphorus constituent was very brittle, the properties of the metal would largely partake of the properties of the constituent. Further, it was broken up by something which was weaker still, and that was graphite. Cast iron had a very weak constitution, having a tensile strength often as low as 10 tons per square inch, whereas in many other products—steel, for example—they would not look at anything under 30 tons to the inch. If they took an ordinary casting and broke it, they could see the graphite on the surface and actually mark with it on paper. If they broke it, it would break along the graphite plates and on some of the pieces of the phosphide constituent.

He thought it was well worth while that they should thus be able to picture the internal structure of cast iron. He thought they would readily relate his remarks with the familiar effect of adding more phosphorus. In stove castings they used higher phosphorus content, and what they were aiming at was the other property of forming a sharp casting, but those castings were very brittle. The structure of steel was represented in a slide which showed the constituent containing

carbon and the pure iron. The next slide showed the steel after the annealing process had taken place, and the lecturer pointed to the absence of the crystalline or tree formation, although there were suggestions of it.

Until lately very much had to be done by judgment of temperature, and the methods of taking the temperature of molten metals were still commercially to be developed. There were methods, it was true, but some of them were so clumsy as to cause interference with practical work, and they could not be adopted as a regular check or control on work. He would include the optical and radiation pyrometers. On small castings the delay due to their use was quite intolerable. He had always had a desire for some sort of pyrometer which could be put into the molten metal, and Mr. Kayser and the lecturer had been experimenting with a pyrometer which was built upon a very simple principle. The pyrometer was shown in a sketch on the screen, and the lecturer produced one of the instruments which had been used in work. The principle, said the lecturer, was that of getting actual metallic contact between the bare ends of the thermocouple wires and the molten metal. They had another under experiment which was 6 ft. 6 in. long, and was suitable for crucible, ladle and electric furnace work; and another which weighed two hundredweights which was used in the Siemens furnace successfully. It took about ten seconds to get a reading which was independent of personal error.

Coming to the last section, the question of casting conditions, regarded as distinct from moulding and the metal itself, it was worthy of some special attention. He had said a good deal about the temperature of metal, but it was quite impossible for him to prescribe a definite temperature at which, for instance, 0.35 per cent. carbon steel ought to be cast, without entering into various details as to the mould and all the conditions attendant on the moulding. For a big casting a lower temperature would do, for two reasons; one was that the time of solidification in the mould was going to be greater, and the other was that the steel would probably be cast at a greater speed in the bigger casting than in the small casting. For a very small thin casting they must cast hotter, or the metal would not get there. It would simply close up the passages before it got into the thin sections of the mould. With those very thin sections, although moulded in sand itself, it was almost the same as though they were dealing with a chill mould. The sole difficulty was to get the metal in at all. Now if he had used the expression "casting temperature," he wanted them to look at it with the idea that it was bound up with the idea of speed of teeming, when the metal was going into the mould. Casting conditions were scarcely separable from moulding. In the foundry, when pouring from a shank, the stream of metal was a very indefinite thing. It was a splash or a throw, or something very little better. When teeming from a nozzle it was very much better defined. Just what happened in the mould when it splashed through might have been thought out, but it was pretty hard to conceive, and the marvel often was that the mould was filled properly and that a clean casting could result. He pleaded that all those things ought to be taken into consideration along with the other controllable casting conditions. Personally, however, he felt that they had at the present time most to gain from the definite study and control of casting temperature itself.

Discussion.

THE CHAIRMAN, referring to Dr. Rogers' observation about Tubal Cain, considered that the time was arriving when the successors of Tubal Cain should work out these problems, and one of the main objects of the Foundrymen's Institution was to encourage concentration on the study of that technical subject which would enable the foreman, manager and moulder to anticipate the different difficulties he would have to deal with, and so arrange that they did not happen.

COMMANDER JACKSON referred to the question of the regeneration of sand after it had been in contact with the metal. They had been enlightened upon the colloidal properties of clay; but he thought they could not very well regenerate burnt clay. Also with flour, after it had been baked into bread, he did not think they would be able to get it back into flour again by any process of regeneration. He was, however, sorry to hear that up to the present the regeneration of sand had not been a commercial success. It would be a matter of great interest to all firms if it could be done.

MR. STOBIE suggested the lecturer meant the displacing of de-hydrated clay and supplying its place with fresh clay. It would seem to be wrong to put sand right with added clay, because they had a mixture of de-hydrated material which was less refractory than sand; and was not the use of freshly-added clay likely to cause trouble? There was another binder, and that was dehydrated oxide of iron.

DR. ROGERS said that so far as he knew the only line upon which it had been tackled had been by the addition of something in the nature of clay, whereas what they wanted to do was to restore to the burnt clay its original colloidal condition.

MR. BROWN ventured to say that 40 per cent. of the defects of castings were due entirely to the design. If the engineer would come down from his pedestal and consult his foundrymen he might get ten times better results than he was getting to-day. He would like to ask Dr. Rogers which was the best way to run a cylinder. He would never attempt to run it from the side or the bottom.

THE CHAIRMAN asked why a cylinder should not be run on end.

THE LECTURER pointed out that his illustration was intended to convey a part of a casting and not necessarily a separate cylinder, which might be handled in the most convenient way. He was merely showing the enormous difficulties and the liability to defects. It might be cast in an inclined position, or it could be run from one end. It altogether depended upon the casting as to whether that were possible. If it were ¾ in. thick and 18 in. diameter it would probably be very dirty, and it was doubtful whether they could get it anywhere like useful.

MR. KAYSER said Dr. Rogers had referred to the attack of the metal on the sand, and he understood him to say that the reason that steel attacked the sand more than other metals was due to the higher temperature of the casting. It seemed to be affected by the properties of the metal far more than the temperature. If one took a little chromium steel and cast into approximately

the same moulds, they would find the metal would have as good a side as if it had been cast iron, whereas the steel casting would come out like a piece of sandstone. Dr. Rogers had classed carbon and graphite together in a way which he did not quite like. Where the flaky graphite was used it did not appear to have much effect in large work, but in small sizes, which were cast in steel at a high temperature of about 1,450 deg. C., it was almost impossible to get the casting to run out. If one deposited amorphous carbon the metal ran quite satisfactorily.

THE CHAIRMAN asked whether Mr. Kayser was speaking of green sand or dry sand.

MR. KAYSER said he meant either green or dry sand. He had only worked in a small foundry, where crucible practice was the rule. They simply did not understand the care which must be taken to keep out such inclusions as Dr. Rogers had shown in his slides. Their ideas of mopping and skimming were most crude. Referring to casting temperatures, he had had the pleasure of helping Dr. Rogers. They did not use the pyrometer in every casting they made. He thought the method of dealing with temperature as it stood to-day could be improved upon by not relying upon colour. That was the usual method, but much depended upon atmospheric conditions. One quick way was to have some standard rod and place it in the furnace for ten seconds, and then take it from the furnace and see the effect upon it. He had seen it used quite successfully on electric furnaces. In crystal steel and small work, he tested with the rod and saw how soon it scummed over, and he thought that was a very good guide as to the temperature of the metal, which did not depend upon the optical conditions of the shop.

THE CHAIRMAN: Holding the rod over the metal requires very great dexterity. One must judge that one has the same distance every time.

MR. KAYSER said that if it was applied it would be found to be very successful. When they saw any sort of scum over it they were satisfied.

DR. ROGERS: You are quite right about dexterity.

MR. KAYSER said, continuing, that blow-holes might have three distinct causes, and it was absolutely impossible to distinguish between them. It might be gas, entrapped air and gases given off by the mould.

MR. SHAW said he could not see eye to eye with Dr. Rogers on the subject of the regeneration of sands. That had been done by him by the addition of clay and the addition of colloidal silica. It had also been done to a very great extent by the Germans before the war. About sixteen years ago it worked very successfully. That was to say that for about two or three months it worked very successfully, and then every casting scabbed. It was not so much the cost of the sand as the carrying of it in and out. Sometimes they had 80 tons a day in the shop. It was not the cost of the sand, but the bringing in of the new sand and the transportation out. The fault was this: when they dried their sand they reduced the clay, and the clay was the finest part they had got. When they had burnt it they reduced the clay to a dust, and that was the chief objection to the addition of the clay. There was not the slightest trouble in adding clay, but they got that very fine substance in the sands from the reduction of the hydrated clay, and they spoiled the porosity of the sand. As they used more clay they got a fine dust, which could be passed through a fine screen. The Americans were using clay, and how far it was going on he did not know. If they could destroy the fine material from the binding sand he thought it was a practical proposition, but whether it was a paying proposition with the sand they had he did not know. So far as casting was concerned, he had seen hundreds of pipes 36 in. in diameter run from the side and the bottom, and those pipes would stand 200 lbs. water pressure. There was, of course, a danger of getting a fault. All the dirt collected upon the top. In cast iron they could run in any of those ways practically, and do them regularly, and there was no fault.

THE CHAIRMAN said that about the 200 lbs. pressure: even 600 lbs. to the sq. in. was insignificant compared with the strength of the iron, so that the fact that a casting would stand the pressure did not mean to say that the foundryman should be congratulated.

DR. ROGERS, replying to Mr. Wills' remarks about oxide of iron, said he scarcely saw that it would be a practical method. It might be for iron, but not for steel. Oxide was hardly the ideal binder, though they were all open to ideas about other binders. He knew it was one of the live matters to-day, and he did not think they should forget the problem about turning a brick into white clay. It could be achieved. As to the use of colloidal silica, he thought the investigation very important, because of the heavy costs of transit. Mr. Kayser had said he did not think it was a question of the sand upon the surface of the mould, but there were moulds without any colloidal property. As to the question of the pyrometers, many of them had their own kinks for measuring temperatures. In plenty of shops which he knew, they put a bar in and measured how much of the bar was bitten off in so many seconds, and that gave them a very admirable guide. One of the most important points in connection with the regeneration of sand had been brought out by Mr. Shaw—that was the fine powder which was created. It would be much better, however, if all that clay could have its colloidal property restored. They must not forget that they still had the essential constituents. They must not look upon the problem as unsolvable. There were certain clays which could be turned into a kind of jelly, and others in which there were changes which were quite comparable with the change which took place in burnt sands.

BIRMINGHAM BRANCH.

The Elements in Cast Iron.

At a meeting of this Branch of the Institution on February 12, when Mr. Holberry (Vice-President) presided, Mr. F. C. A. H. Lantsberry, the President of the Birmingham Metallurgical Society, discussed "The Relations between Iron and Some of the Elements making up Cast Iron."

The speaker showed on the screen the thermal equilibrium diagram, which he explained. The foundrymen had sometimes to produce iron containing a large quantity of graphite and very little combined carbon. In other cases he had to produce castings containing almost no graphite, but in which the carbon was all in the combined

form. By causing the cooling to be very slow indeed, they minimised the chance of undercooling. Slow cooling tended to give graphite, while rapid cooling tended to produce cementite. They could get a graphitic condition by prolonged annealing at some temperature just below the eutectic line, and that was the process which the malleable-iron founders made use of in producing supposed malleable castings. They could get that condition of equilibrium by modifying the composition of the material. The silicon tended to throw out the carbon in the graphitic form. Sulphur by itself in an iron containing no manganese tended to keep the carbon in the combined cementite form. It was generally assumed that sulphur did this by forming a sort of water-tight compartment round the cementite which prevented it from doing what it ought to do.

Manganese also retarded the precipitation of the graphite. Phosphorus was a very useful element to the iron founder, and the relations existing between iron and phosphorus had been stated by Dr. Stead, whose work had been added to that of Saklatwalla. In the iron-phosphorus series iron was capable of dissolving 1.7 per cent. in a state of solid solution, but the iron-phosphorus system, in spite of the attention it had received, required considerably more investigation. The addition of 1 per cent. of phosphorus decreased the melting point by about 27 deg. C.

Dealing next with the ternary eutectic, the speaker showed that this contained roughly 91 per cent. of iron, 7 per cent. of phosphorus, 2 per cent. of carbon, and had a melting point of 945 deg. C. If carbon was added to iron containing 1.7 per cent. of phosphorus, the solubility decreased very rapidly. So much so that phosphorus was almost completely insoluble in iron containing 1 per cent. of carbon. The primary crystals which were deposited on solidification of the metal were free from phosphorus, and ultimately the phosphorus was aggregated in the ternary eutectic. The speaker explained at some length the precise conditions connected with the binary and ternary eutectics.

The relations between irons and silicon had been very thoroughly investigated. Silicon would dissolve in iron up to a content of 20 per cent., so that all the silicon found in the cast iron occurred in the state of solid solution.

Discussion.

Mr. Hayes, of the Birmingham Metallurgical Society, said the Paper was very welcome in view of the fact that the pig-iron which foundrymen had to use to-day was considerably inferior to that supplied pre-war. This did not make much difference to the production of large castings, but when it was attempted to produce small castings alongside very large ones, which necessitated ladling from the large ladle to the small ladles, many difficulties cropped up owing to the low temperatures which ensued. The most prevalent trouble which was met with in the foundry was the hard shot in small castings, which made very difficult the machining of them. In some instances this trouble was traced definitely to the rather extravagant use of the water brush on the part of the mould maker, this resulting in the formation of oxide produced by the reaction between the molten iron and the mould surface. Undoubtedly the majority of this type of fault appearing in small castings was owing to the fact that as the temperature was lowered by ladling, the phosphorus and sulphur concentration in the iron was considerably increased, and this probably was the cause of this type of fault. He had found that the most satisfactory way of dealing with the matter was to work a small cupola for small castings. A small cupola would assist in overcoming the difficulty by giving higher temperatures. There would also be less handling of the material in passing it from one ladle to another, which, of course, would get over the difficulty of falling temperatures after the iron had left the cupola.

The Secretary (Mr. H. Field) said that, in spite of the large amount of technical data already available in regard to cast iron, there were still many difficulties which the equilibrium diagram failed to explain. He did not think Mr. Hayes had quite got hold of the root of the trouble experienced in his foundry. The bulk of light castings made in the country were produced with iron exceeding 1.5 per cent. of phosphorus. One constituent of cast iron had not been touched by the author, namely, oxide. The iron now used contained a considerable proportion of iron oxide, and he thought that that was very largely due to the fact that so many blast furnaces were working irregularly through lack of coke. So far the equilibrium diagram had not helped him to explain the production of white iron in light castings from iron containing 3.5 per cent. of silicon and 1.5 per cent. of phosphorus, particularly where there were no signs of burning in the castings. The iron which ought to be grey showed white patches, occurring at short intervals through the heat. In this case the carbon and the silicon were normal and the sulphur not more than 0.06 or 0.07, yet they had these regular occurrences of white portions.

Mr. Gaunt remarked that it would help them very much if Mr. Lantsberry could tell them the various mixtures required for castings of different descriptions. There was not much hope of their reaching the ideal standard of knowledge for many years, and such data as he had suggested would be of the greatest value, and he would like to have some indication of what it would be useful to tell the men in instructing them in the annealing process.

Mr. Johnson said that some of the remarks made in the discussion were very interesting to him. Mr. Lantsberry was being appealed to to instruct foundrymen in matters in which, if he might be excused for saying so, were quite outside his province. Such information could only be obtained by foundry workers going in for technical education. Mr. Lantsberry had referred to alloy-systems in which a single series of solid solutions is formed from one end of the diagram to the other, and had stated that in any cast alloy of such a series the crystals would never be homogeneous. He would, however, point out that there were some series of binary alloys which formed a series of single solid solutions having for a certain composition a minimum freezing point, at which point the crystals were quite homogeneous, as shown by microscopic and thermal examination. An example of such a series were the copper-manganese alloys. Mr. Lantsberry had supported Levy's view of the retention of carbon in the carbide form, due to the emulsifying influence of sulphide of iron. Mr. Johnson would welcome his views on later theories, *e.g.*, that of Dr. Stead.

Mr. T. P. Colclough thought that, so far as silicon was concerned, it was exceedingly difficult to forecast what the effect of a certain amount of

silicon was going to be. It was impossible to say that if 1 per cent. would have a certain effect that 2 per cent. would have a double effect, because the effect of silicon depended very largely upon the rate of cooling and the amount of the other elements present. Its effect is not absolute, but "conditional" on other factors. With regard to sulphur, he thought the question of the influence of silicon and sulphur had been pretty well thrashed out by Dr. Hatfield in his book on Cast Iron (recent edition). Dr. Hatfield's opinion was that Levy's suggestion as to the balling-up of cementite or the formation of films which prevented the decomposition of cementite was not correct, but that the influence of sulphur appeared to be due to the formation of a compound of silicon and sulphur. Possibly, if that was the case, the silicon had its influence neutralised because there was not so much "free" silicon present and able to do its work. In addition to the evidence of Dr. Hatfield in that matter of cast iron they also had the work of Professor Arnold and two or three German workers, in which they had definitely proved that in steel, in the cast condition, there were in the cleavage planes of cast steel films of a compound, or a eutectic of silicon and sulphur, really a silicide eutectic. He (the speaker) thought that explained fairly well the reason for the action of sulphur. Certain micrographs had shown very clearly that with the addition of 0.5 per cent. of sulphur and low silicon it was almost impossible by annealing cast iron about 900 deg. C. to get a precipitation of the graphite.

As to the effect of silicon in producing grey cast iron, practically all the silicon they got in steel or cast iron was in solution in the ferrite. Mr. Lantsberry had said that the primary crystals which separated out would be rich in silicon and containing practically the whole of the silicon. So in the needle-like crystals of cementite they would have portions free from silicon. That was rather incompatible with actual practical experience, and required some modification, for it was found in grey or malleable iron that the cementite crystals decomposed first, giving graphite surrounded by ferrite masses.

The thermal equilibrium diagram was exceedingly interesting from the theoretical point of view, but the difficulties arose from two facts—(1) that the diagram did not recognise the effect of varying rates of cooling; (2) that those diagrams were worked out from two or three elements, but in iron castings they generally had five or six elements, and therefore they would get a new set of conditions. So far as he could see at present, it was impossible for the foundryman to apply those diagrams to his everyday work, and the only hope they could have was in the extension of the present system, whereby technical men were being imported into the foundry to study questions from the practical point of view. In that way practical experience would be handed on to the next generation, who had received technical education for themselves, and who would then be better equipped to study the problems and so produce better castings with fewer failures.

Mr. Lantsberry, replying to the discussion, said that several speakers had alluded to the fact that the equilibrium diagram frequently failed to explain practical difficulties. That could really be very easily understood, having regard to the fact that the diagram referred to the condition of alloys when equilibrium had been attained. But the equilibrium diagram also indicated the changes which the alloys had to go through in order to attain that equilibrium. In practice equilibrium was attained only on very rare occasions, and when that happened the product was often only fit for the scrap heap. But it was absolutely essential all the same that the workers should know what was going to be the ultimate end of the materials if they carried them to the point at which complete chemical equilibrium was reached. If the foundrymen would tell them their difficulties and give them an opportunity to study those difficulties from every point of view, the men of science could really give them assistance. Research would tell them what to put in the iron, but he had tried to explain that it was not altogether what they put into the iron that determined what they were going to get out finally, but also it depended upon what was done to the material. Mr. Colclough had told them that the effect of silicon in iron was conditional, and that it was a mistake to suppose that if they had 2 per cent. of silicon the effect would be double that of 1 per cent. That effect had often been demonstrated. In many cases found in scientific research the minutest trace of another material was quite sufficient to bring about the changed condition, while the addition of a further material was just as likely to make it turn round and stop the change altogether. He did not propose to enter into a discussion giving his real opinion as to the actual effect of sulphur. He was afraid he could not agree that that matter had been settled beyond doubt. He believed it was a matter requiring further research. But he thought he had indicated his opinion with regard to the mulsification theory. Mr. Colclough had referred to the crystallising out of silicon in the primary crystals, but in that particular case they had to remember that the condition of the third material complicated matters and displaced almost everything.

COVENTRY BRANCH.

Silicon in Cast Iron.

Before the Coventry Branch of the Institution of British Foundrymen recently, a lecture was delivered by Professor T. Turner (Birmingham University) on "Silicon in Cast Iron."

The lecturer, after describing some of his early experiments, said that experience showed that circular bars gave more regular and more uniform tensile results than did rectangular bars. The results of the tests he made showed that the crushing strength increased as the silicon was increased, and then with further silicon gradually fell off; that the tensile strength increased and reached its maximum with something just under 2 per cent. of silicon (about 1.8 per cent.), and then with more silicon added the metal lost its high tensile properties and gradually became a weak and brittle material (Fig. 1).

With 2 per cent. silicon the carbon is chiefly in the free state, and the material is grey iron. That corresponds with 15.8 tons per sq. in., which at one time was the record tensile strength for British cast iron. To illustrate how science has progressed in the interval, many firms will guarantee a tensile strength of 15 tons, 16 tons, or even 17 tons per sq. in., and will maintain that for a period; and it is not uncommon now to have cast iron with a tensile strength of 19, 20 or 21 tons. As much as 22½ tons has been authenticated after careful experiments. At the time of the

author's experiments, however, there had been no British iron recorded of a strength over 15.8 tons per sq. in.

The best way to illustrate the difference between the two forms of carbon was to take a few turnings and rub them on the palm of the hand. If turnings of wrought iron or steel or white cast iron were so rubbed the hand would remain clean. But if the same thing were done with grey cast iron or any iron containing free graphite the hand would be nicely polished with the graphite which came out of the iron, showing that the carbon was in the free condition.

The series of experiments to which he had referred showed that one could commence with white iron, and by adding silicon alone could convert the white iron into grey iron, the grey iron into very grey iron, and the very grey into an iron almost rotten. It would thus be seen that there was a certain proportion of silicon which gave the best results in practice.

A small casting would cool more rapidly than a big one, and a casting made in a chill would cool more rapidly than one cast in sand. It must be remembered that the effects of the proportions of silicon which were found in his experiments only applied truly in the circumstances of those experiments. There were three things to be remembered in reference to those circumstances; first, that he started with a pure cast iron lower in carbon than usual, so that there were no interfering elements, and nothing unusual except the somewhat smaller proportion of carbon; secondly, that the casting was one inch in diameter; and, thirdly, that his samples were all cast in an ordinary green-sand mould. In those circumstances 1.8 per cent. or thereabouts of silicon remained correct up to the present time, as giving the best tensile strength.

Now, one of the most remarkable things in connection with silicon was its effect upon the hardness of cast iron. At that time there was no method known of determining hardness in

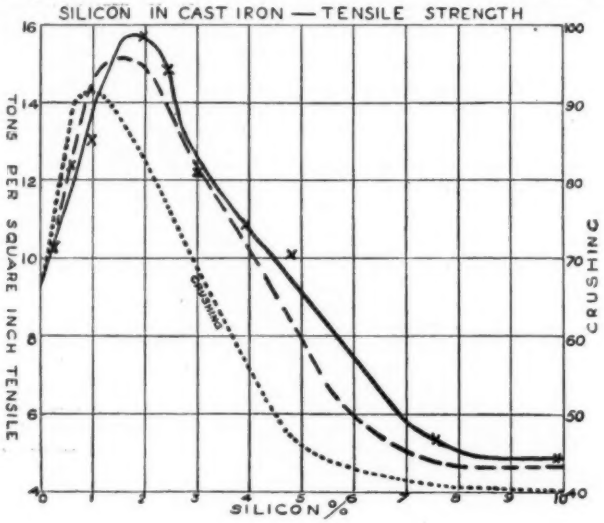


FIG. 1.

With the object of strengthening cast iron by the addition of a suitable proportion of silicon, some people tried to mix the irons together without a proper knowledge of their composition, or without chemical analysis to guide them as to what mixture they really obtained. Thus silicon was condemned not for any fault of its own, but because it was used in the wrong proportion. Others neglected the fact that the properties would be profoundly influenced by the other constituents—the amount of sulphur or phosphorus or manganese, or even of total carbon. It would thus be seen that, whilst silicon was the controlling element in the foundry, one must always bear in mind that the proportion of silicon that would be required in a particular mixture would depend upon various circumstances. The most important factors were, first, the proportion of other elements that were present; and second, the rapidity of cooling, because rapid cooling tended to keep the iron and carbon combined. In other words, chilling tended to retain the carbon in solution and to give a white iron, whilst slow cooling gave the graphite time to separate, and made the iron more grey.

metals—no recognised method, though there had been certain experiments. Therefore he had to introduce a method of testing hardness, and a method that would cover a wide range. That was done by means of a weighted diamond. They started with a material containing practically no silicon, and sufficiently hard to scratch glass readily.

On adding silicon the hardness rapidly fell, until they came to a material which could be easily turned or cut. The iron with about 2½ per cent. of silicon gave the maximum softness. On adding more silicon the hardness increased. Now, that change showed the observant student that in all probability there were two effects proceeding side by side. There was an immediate effect, making the metal soft, and another effect, which came in more pronouncedly afterwards, of making the metal hard. The explanation was that the silicon when first added threw out the greater part of the carbon into the free form and left the iron without the carbon. The purer the residual iron the softer it was. But when one came to the point where practically all the combined carbon had been

taken out the iron was perfectly soft, and could not possibly be made softer. Hence all the silicon afterwards added, like any other element that went into solution, tended to harden the iron. The formation of a solid solution always led to a hardening of the iron; the silicon, even from the beginning, was hardening the iron, though this effect was disguised by that resulting from the throwing out of the carbon. But as the carbon was thrown out the effect of the silicon was gradually more and more seen until the curve in the diagram became almost a straight line, indicating that the hardness increased proportionally with the increase of silicon (Fig. 2).

Those experiments only dealt with metal containing up to 10 per cent. of silicon. But experiments had since been conducted, some in the Birmingham University laboratory, others in laboratories in different parts of the world, and also by many manufacturers, with the object of using ferro-silicon made in the electric furnace, and containing higher proportions of silicon. Experiments had been made with proportions of silicon as high as 50, 75 and even 90 per cent. On examining a melting-point diagram illustrating the properties of irons rich in silicon, the important point to notice was that if they started with iron melting at 1,500 deg. C. or thereabouts and added silicon to it in successively increasing proportions, then the melting point of the mixture fell till they got to the eutectic composition. That occurred when the proportion of silicon by weight was something under 20 per cent. On adding more silicon they obtained a compound, FeSi, which had a higher melting point. With more silicon still they found a second eutectic, and then the melting point rose steadily to that of silicon, about 1,425 deg. C. Therefore, if it was desired to obtain a casting in silicon-rich iron, as, for instance, in making acid-proof vessels, the point to be aimed at was to put as much silicon into the mixture as could be introduced without reaching the eutectic point. Once that point was passed, the melting point rose and a material was obtained which was very difficult to deal with, whilst so long as the silicon was kept somewhere in the neighbourhood of 18 per cent. it was quite easy to melt the material and pour it into a mould. That mixture, in fact, was very satisfactory.

He had said that the amount of silicon that was required depended upon the amounts of the other elements present. That was particularly true of carbon. If the total carbon was high, say in the neighbourhood of 3½ to 4 per cent., then it required relatively little silicon to throw out that carbon in the form of graphite. They knew by experience that if the graphite once began to form, and the material was maintained at that high temperature, the rest of the carbon would follow. As in many cases of crystallisation, when once crystallisation was started more crystals were formed. But if the carbon were low, say in the neighbourhood of 2½ to 2¾ per cent., it would be necessary to add more silicon to throw the carbon out of solution. In fact, silicon had to be added to form the lower silicide of iron, and to leave behind only enough free iron to retain the carbon.

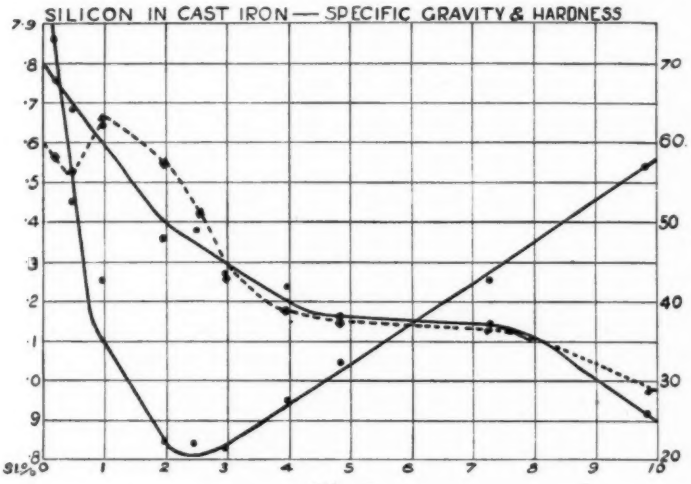


FIG. 2.

In other words, the silicon for the purpose of solubility used up some of the iron, and then began to throw out the carbon; but if there was little carbon there more iron was free to be occupied with some other element before the carbon could be thrown out. The primary or fundamental effect of silicon, therefore, was on the carbon.

One result of that was that the more carbon was thrown out of solution the less would the metal shrink, because the carbon was light and bulky when in a separate form. Hence, in making a cast iron with white iron more shrinkage had to be allowed for than in making a grey casting. When the white iron used in the malleable trade was annealed as was done in making the ordinary cast iron, than an expansion took place, and the net result of the extra shrinkage and expansion was very similar to what would be got with the ordinary grey iron.

There was no better rough test of the character of an iron than to determine its shrinkage. This was first suggested by the late Mr. W. J. Keep, of Detroit. The practice was to take a small quantity

of metal out of the cupola, pour it into a mould exactly one foot long, and get a bar which would be one foot long, less the shrinkage. A little wedge was put in between the yoke and the cold bar to determine the amount of shrinkage; and it would be found that the character of the product could be predicted with considerable certainty when the shrinkage was known.

If phosphorus and silicon were present together the result was grey iron with phosphide eutectic. The main portion of a very grey iron was silicious iron or silico-ferrite, and the graphite was in big flakes. That was not good if they wanted the best quality iron; it would do for bedplates and railway fishplates and chairs, and so forth. But it would not do for engine purposes. To improve this iron for such purposes, they had to distribute the carbon, and as far as possible distribute the phosphorus; to make a good cast iron all the constituents should be distributed equally throughout the metal.

Taking an example of a No. 1 pig-iron, this would be unsuitable for foundry purposes except for a very limited number of applications. This iron contained carbon in the form of very large flakes of graphite, and practically no combined carbon, whilst the phosphorus was unevenly distributed.

The iron which would have the best mechanical properties, combined with good machining properties, having density without undue hardness, a high tensile strength and a capability of wearing well, was one which contained just sufficient silicon to throw out the greater part of the carbon in the free state, but to leave sufficient combined to be just under the eutectoid proportion. It should be on the soft side, and have the pearlitic structure distributed as far as possible all through the material, and then the best result was obtained.

The lecturer, in conclusion, said that the proper use of silicon was the key to the management of foundry irons. This could be done without any increased cost. They need not buy silicon. They could always buy good pig-iron containing silicon, and by the use of this iron they could make a mixture suitable for any purpose they might have in view.

BIRMINGHAM BRANCH.

Science in the Foundry.

The following is the discussion on the Paper (see our last issue) read before this Branch:—

The President referred to the lecturer's remarks on the application of science to foundry work. It was obvious that if they were to go ahead and develop the industry they must go further in that direction. He cited a case when his foundry was called upon to make some bronze castings 6 in. diameter, 1½ in. square, cored out to leave about 1½ in. of the ring solid. Although the job was given to different men, not one could produce a good casting; and when upon investigations the workmen reported the trouble as being due to trapped air, he suggested that the cores should be made with wax core wires for vents. Upon this being done the trouble immediately disappeared. This was an instance of how time and money could be saved with a better dissemination of knowledge. With regard to Mr. Harley's remarks as to trying to give boys practical training in Universities and technical schools, he quite agreed, but contended that the best instruction could only be given by practical demonstration.

Professor T. Turner said that some of them could remember the time when it was not possible from chemical analysis to predict what were the physical properties of a material with which they had to do. They now knew pretty definitely what structure would be obtained with a given chemical analysis if they dealt with it in a standard manner. He remembered when a tensile strength of 15.8 tons per square inch was a record for British cast iron, but Mr. Harley had shown several diagrams in which that figure had been exceeded, and regularly for a long period. They knew from experience that that could be done, and was regularly done. Such results were only obtained as a result of scientific knowledge and foresight. He very much sympathised with the reference that was made in the Paper to the importance of some knowledge of foundry work before the scientific man began to apply his knowledge in connection with the work. For a mere chemist, or a man who had merely had a training in a scientific institution, to assume that he could at once take charge of a foundry would be one of the greatest mistakes.

Mr. F. C. A. H. Lantsberry said the lecturer had demonstrated the real practical use which could be made of a thorough understanding of the fundamental scientific principles on which a particular branch of industry was founded. With the first part of Mr. Harley's Paper he was in absolute agreement. He thought the most important part of the Paper related to co-operation between science and practice in industry. It was absolutely essential nowadays that the various technical men and the commercial men should closely co-operate with each other, but there was some little difficulty in that co-operation, although he thought Mr. Harley had pointed out the solution. The difficulty was found in the fact that no matter how complete a man's knowledge of a certain branch of a subject might be, and no matter how complete may be another man's knowledge of another branch of the same subject, it was absolutely impossible for them to co-operate unless each of them knew some little of the other man's subject. He (the speaker) suggested, in regard to the question of testing rings, that it should be possible to deduce a formula to give the exact tensile strength of the ring, no matter what the shape might be, because he understood from Mr. Harley that that formula was devised more or less empirically.

Mr. Holberry said it was very common for the foundry manager to have his plans completely upset because the man in charge of the cupola had no technical knowledge of his work. It was also very important to have the foundry properly lighted and heated, and that was a matter which foundry managers and employers of labour generally should give a great deal more attention to. He would like to know whether Mr. Harley found a deeper chill when casting at a high temperature or at a low temperature.

Mr. Pemberton (Derby) said the lecturer had made reference to a good organisation as regards lighting, heating, the running of orders, the work of the order clerk and all that kind of thing. He (the speaker) thought it rather an important point to start, as Mr. Harley had done, with the organisation, probably on the receipt of the material. All the material coming into the works should be sampled, and the result of that sampling should be known and the analyses should be furnished to the foundry manager with the idea of helping him to make his mixtures for various cast-

ings. Mr. Harley had shown the use of chemical analysis and the various irons used in piston rings. Those irons were obtained, he (the speaker) presumed, by very careful organisation, by analysing the materials when they were received, and not allowing them merely to be sent into the works. Obviously, unless these facts were ascertained it was impossible to make the correct calculations to get the right results. Mr. Harley had not only obtained results, but he secured them as they were predicted from the chemical and physical point of view. With regard to piston rings for aero engines, he quite agreed with the analysis put forward for that class of ring, which, as he knew, was only a 4 in. ring running up to $\frac{3}{8}$ in. thick. At the works with which he was connected they made a lot of piston rings, some of them larger than those described by Mr. Harley for locomotive work. At the same time, he thought the chemical analysis which Mr. Harley had given was not quite suitable for locomotive-engine piston rings. He thought especially that the silicon was on the high side. The lowest silicon shown by Mr. Harley was 1.5, running up to nearly 2 per cent. The test obtained was a very good one, but, personally, he believed that the same test could be got with a lower silicon, say 1.2, and with a total carbon of not more than 3.4 per cent. That 3.4 per cent., with 1.2 of silicon, and with the sulphur as Mr. Harley had shown, was rather higher than they would like to use in engineering works. The sulphur, in particular, they looked upon with suspicion. Undoubtedly it had been proved that rings could be made up to 0.14 of sulphur, but with a high percentage of sulphur the moulder was not satisfied, and he was apt to complain, and if he got complaints of the results of the castings he invariably said it was the sulphur which caused the trouble. Mr. Harley told them that very good rings could be made with 0.42 per cent. Personally, he did not doubt that, but he could not help thinking that they ran a large amount of risk with that proportion, because the metal had to be poured at such a very high temperature, and unless that point was known they would be running a great deal of risk, and it would be necessary to follow that metal round through its processes and take care that it was put into the mould at that very high temperature. The iron was very often blamed, and undoubtedly the moulder was nervous about his mould if he cast it at that very high temperature, and he generally said when anything was wrong it was the fault of the iron.

Mr. Harley, replying, said it was clear that most of his hearers were in agreement with him on the general principles which should guide them in the application of science to foundry work. The slides which he had shown were the practical results of work done, and, to a large extent, spoke for themselves. With regard to a very fine network structure shown in one of the slides, he called attention to the formation of primary crystals, which was explained by the fact that the metal was cooled down very suddenly. That ensured the retention of that structure, but with slower cooling, as in the sand mould, it was lost. With regard to the question asked by Mr. Lantsberry, the rings were tested with the gap, this gap being at right angles to the direction of pull. As to the effect of casting temperature on the depth of the chill, it depended, first of all, on the composition of the metal, and, secondly, of the temperature of the chill; but, generally speaking, he found that they got a greater depth of chill as the difference between the temperature of the metal and the temperature of the chill increased. Therefore, with the metals he had been handling, they got a deeper chill when the metal was cast hot than when it was cast cold. It was sometimes contradicted with other compositions—manganese having considerable effect—but that was his usual experience.

One or two speakers had referred to the high sulphur employed, but he had not put forward high sulphur metal as the standard metal to be used, although it did not show any inferiority in the tests. However, it was undoubtedly true that many people were rather afraid of, or at any rate very suspicious about, the use of high sulphur in rings. That was a matter on which there were differences of opinion, but the result of the high sulphur experiment referred to had no doubt some influence in the greater tolerance allowed in the official specification.

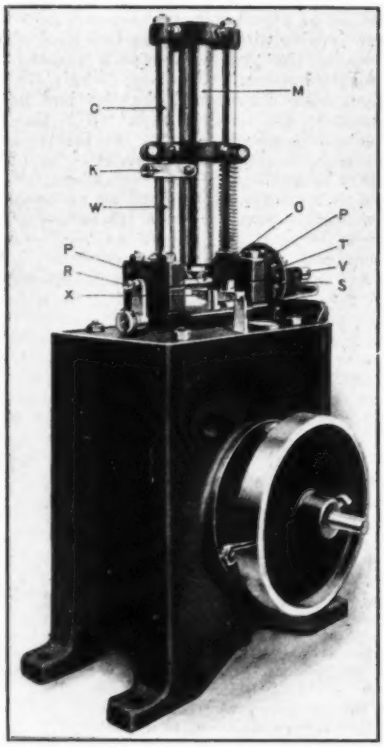
It had been complained that he had not been quite just to the foundry chemist; he thought he had been misunderstood, for certainly no one valued more highly than himself the foundry chemist. What he was referring to was the small isolated laboratory. It seemed to be the idea of some manufacturers to run a laboratory with the minimum expenditure. Such an employer could not very well obtain the best results. In such cases the chemist was not always competent to apply the data in his possession in a practical manner to obtain better results, and if the employer himself could not do so, the result was a certain amount of prejudice against scientific work in general. Firms who knew their business were now equipping laboratories in a manner never dreamed of a few years ago. They were employing the most competent men they could lay their hands on, and the foundry chemist was beginning to have his status properly recognised.

THE INDUSTRIAL USE OF HIGH PRESSURES.—A writer in a recent issue of the "Technical Journal" says that in industry we do not ordinarily go beyond 20 or 30 atmospheres. When, in the liquefaction of air, pressures of 150 to 200 atmospheres were used, it was regarded as a marvellous achievement in mechanical science, and as probably the utmost limit possible. This opinion is generally held to-day. When the officials of the chemical works at Oppau, in Germany, were explaining to the Allied Commission their processes of manufacture, they made a great point of the difficulty they had overcome in developing the Haber process for extracting nitrogen from the air by applying a pressure of 200 atmospheres to large volumes of hydrogen. The author believes that this view is wholly unjustifiable, and that it would be advantageous and easy to use a pressure of, say, 1,000 atmospheres instead of 100 or 200. Cup leathers, it is well known become more effective as the pressure increases, and the author's experience has shown that they will stand much higher pressure than any they have yet been subjected to. By observing certain elementary precautions he had realised with the help of simple plunger pistons, compressors capable of compressing 100 cubic metre of gas an hour up to 1,000 atmospheres density. To compress to 2,000 atmospheres needs only the addition of one or two small cylinders to an installation for lower pressures. Moreover, the law of isothermic compression shows that the work required to compress to 1,000 will be only 3 as against 2 for 100. A tight joint is more easily made with the higher pressure, for it is correspondingly smaller on account of the reduced size of the apparatus.

New Testing Machines.

Eden-Foster Repeated Impact Testing Machine.

Although it is rather more than 10 years ago since the experiments and investigations of Dr. T. E. Stanton directed the attention of engineers to the method of testing the dynamic qualities of materials by means of repeated stresses of small individual amount, it was not until the advent of the war that the value of such tests received official recognition. In a recent lecture Dr. T. Swinden said :—"Ordinary tensile and static bending tests do not tell us all that it is desirable and necessary that we should know as regards the properties of metals and their capability of



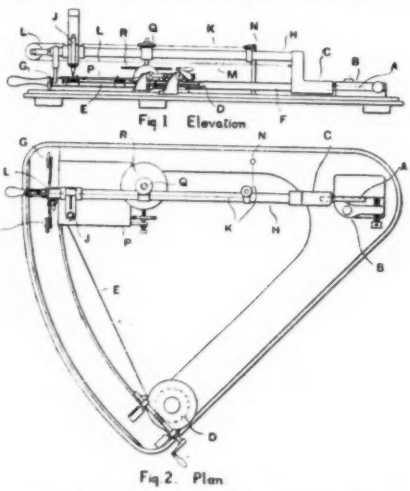
Eden-Foster Repeated Impact Testing Machine.

meeting service conditions. This is brought home repeatedly by the experience common to all engineers that parts of machinery fail in practice under stresses which, according to static tests made before and after failure, should have been without detrimental effect on the material; hence the necessity of dynamic or shock tests of some type or other."

To-day steel-makers and engineers generally are fully alive to the necessity for and the value of the results of testing for shock. For this shock testing the claims of the repeated impact testing machine cannot be ignored, because tests may be made conveniently with different striking energies, whilst if the series of tests is sufficiently extended it is possible to arrive at figures for stress which machine parts could withstand indefinitely without failure. In such a machine, however, it is essential that the true energy of the blows shall be calculable if various results are to be comparable, and there is no doubt that the value of the repeated impact test has been discounted because the design of the particular machine did not comply with the essential condition referred to. Often, again, such machines were made too light, and the lack of rigidity led to varying results according to the nature of the base upon which the machine was mounted.

In the design of the machine under notice, of which the manufacturers are the Foster Instrument Co., Letchworth, Herts., care has been taken to eliminate the defects referred to. The hammer is without attachment and falls freely under the influence of gravity, the falling mass being symmetrically disposed above the point of impact, and as the actual height of the fall is easily measured it is possible to calculate, with a high degree of accuracy, the energy of the blow. The base which supports the machine and receives through the test-piece the energy of the blow is very massive, thus the machine would give equally reliable results mounted upon a wood bench as upon a concrete base.

Referring to our illustration, it will be seen that the whole of the mechanism is secured to and supported



Figs. 1 and 2.—Diagrammatic Plan and Elevation of Humfrey Machine.

by the main casting, which also acts as cover to the tank or box casting. The main spindle projects through the side of the tank and carries the driving pulley as shown, the power taken being 1/10th h.p. The main spindle carries, inside the tank, a dog clutch normally in engagement with, and driving, a cam. A roller which bears on the upper surface of the cam is attached to the lower end of a rod (concealed by the standard G in the illustration), this rod being guided so that it rises and descends with each rotation of the cam. Fixed on the rod is an arm which engages with the lower face of the hammer M; thus, when the rod rises by rotation of the cam, the hammer is also lifted. The hammer slides freely between two sets of three-point guiding screws, which are carried by the castings attached to the standard G. Mounted on this standard is a sleeve W, which is capable of rotating freely about the standard G, but is held normally in a fixed position by a spring, not shown. Clamped upon the sleeve W is an adjustable catch K. It will thus be seen that as soon as the arm has lifted the hammer sufficiently, the spring causes a partial rotation of the sleeve W, so that, when the actuating arm again descends, the hammer is held by the catch K. The further descent of the arm brings its lower-inclined face into engagement with a roller arm, which is so attached to the sleeve W.

that the catch K releases the hammer and allows it to fall on the test-piece O. The test-piece O is carried by two hardened-steel bushes in the plummer-blocks PP. One end of the test-piece is slotted to engage with a universal joint drive, and is kept in engagement by the set-screw R. The drive is by a chain T through a free wheel and clutch S. One end of the chain is attached to the roller which bears on the cam, and the other end carries a weight which is suitably guided; by this means the test-piece is rotated through 180 deg. between successive blows, the movement beginning and ending entirely between the blows.

The revolutions of the test-piece are recorded by a counter V, the number of the blows being, of course, found by multiplying the counter record by two. When the test-piece breaks it comes in contact with the arm X, thereby tripping the clutch and bringing the machine to rest. The tank is partially filled with oil, to provide efficient lubrication for the cam and other surfaces.

It will be noted that the height of the drop depends upon the position of the adjustable catch K; it may be varied from about 1 in. to 4½ in. Two hammers are provided, weighing 5 lbs. and 2 lbs. respectively. With the heavier hammer the machine may be driven up to any speed not exceeding 60 r.p.m., and with the lighter hammer up to about 90 r.p.m.

The machine is adapted for test-pieces similar to those adopted by Dr. Stanton.

Humfrey Autographic Notched-Bar Testing Machine.

The value of carefully-applied mechanical tests to all classes of material is generally recognised, but this

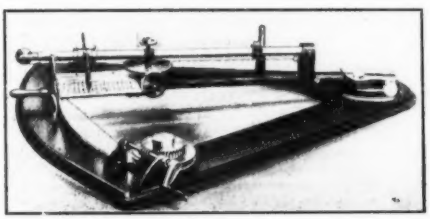


FIG. 3.—HUMFREY MACHINE; GENERAL VIEW.

is perhaps more especially the case with alloy steels which are now being increasingly used in machine and engine parts, and in which a certain brittleness may exist that is entirely unrevealed by the usual static tensile tests. This brittleness may, however, be clearly shown by bending tests upon notched bars, whether broken statically or dynamically. The machine under notice, also built by the Foster Instrument Company, is devised for this class of test, and affords the maximum amount of information in the minimum time.

The standard test-piece is similar to that used for single impact tests in the Charpy and Izod machines, *i.e.*, 10 mm. × 10 mm. section with a round-bottomed V notch cut at the region intended to be tested. Perhaps the most convenient method is to cut several such notches in a long specimen, so that consecutive tests may be made, thus giving information as to the variation in the bar and allowing average results to be calculated.

Referring to our sketch illustration, Figs. 1 and 2, a test-piece of this kind is shown at A. It may be recalled that in machines of the Charpy and Izod class, where the specimen is broken by the action of a falling weight, the test result indicating the energy absorbed in breaking the specimen gives no information as to the manner in which the specimen broke; that is to say, it is not shown quantitatively how far the specimen bent before actual fracture, or whether it was brittle or ductile—two very necessary points for consideration in the classification of the material. It was the consideration of these limitations which led Mr. J. C. W. Humfrey to evolve the machine under notice.

Its principle and construction will be readily understood from our diagrammatic illustration. The test-piece A is gripped in the vice B, so that the jaws of the vice are in line with the notch in the test-piece. The socket C is attached on the projecting end of the test-piece, and is a reasonably close fit thereon. The bending stress is applied to the test-piece by means of the winch D and the wire E, which last is attached to the outer end of the spring-bar F. The inner end of the spring-bar is firmly fixed to the socket C. Its outer end is supported by two rollers G and G_1. The socket C also carries a rigid bar H. The deflection of the spring-bar F is a measure of the bending moment applied to the test-piece. Since the rigid bar H is not subjected to any bending moment, it will move through the same angle as the socket C, and this movement will therefore be a measure of the bending of the test-piece.

The pen J slides upon the rigid bar H, its position being determined by thin wires K-L, which are kept in tension by the spring M. One end of the wire K is attached to a post N, so that as the rigid bar moves in consequence of the bending of the test-piece, the wire K will draw the pen to the right. The point of the pen marks upon a calibrated chart P, carried on the spring-bar F. If, therefore, the test-piece offered

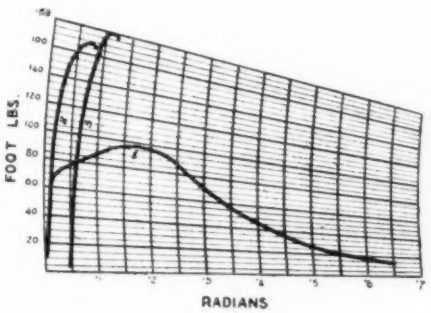


FIG. 4.

no resistance whatever to bending force, the pen would draw a horizontal line on the chart, the length of which is proportional to the angle through which the test-piece is bent. As, however, the test-piece obviously does offer resistance to bending there will be resulting movement between the spring-bar F and the rigid bar H.

Assuming the test-piece was infinitely rigid and did not bend at all under the applied force, the pen would draw a vertical line on the chart, the height of this line representing the magnitude of the bending moment applied. Of course, in actual practice both of these effects are operative at the same time. The test-piece offers resistance to bending, but is nevertheless bent as the force applied increases. The result is the pen draws upon the chart a curve showing the relation between bending moment applied and angle of bending throughout the duration of the test. For example, if the test-piece is of rigid and brittle material, or ductile, the records would be similar to those illustrated, which were made for our representative's information on his visit to the Letchworth works. The curve 1 (Fig. 4) is the result of a test on a specimen of untreated nickel steel. No. 2 is a similar material which has been treated by heating to 900 deg. Fah., quenched in oil, re-heated to 500 deg. Fah., and then allowed to cool slowly in the furnace, for the purpose of demonstrating brittleness. No. 3 received similar treatment to No. 2, but on re-heating was quenched in water. It will be evident at once that the informa-

tion shown by the curves is extremely valuable. It has been found in practice that the correct heat treatment of any material can be determined with ease by testing a series of test-pieces, and steels previously unreliable have been made to give quite satisfactory results on the basis of information so yielded.

The total energy absorbed in the breaking of the test-piece can, of course, be calculated easily from the diagram. Alternatively, the machine is fitted with an integrating device, shown in our diagrammatic sketch (Figs. 1 and 2). The wire K passes through a pulley Q, which is attached to a spindle having at its lower end a friction disc R, so that the bending of the test-piece which results in the movement of the pen to the right also results in a proportionate rotation of the friction disc. The under-face of the friction disc rests upon the edge of a friction wheel (this is not shown). The spindle of the friction wheel is carried with the chart plate upon the spring-bar F. When the bending moment is zero, the friction wheel is at the centre of the friction disc, but as bending moment is applied and there is relative movement between the spring-bar and the rigid bar, the friction wheel travels towards the circumference of its disc, and is thus rotated. Obviously the rotation will be proportional to the product of the bending moment applied and the angle of bending of the test-piece, and this device will therefore integrate the total energy absorbed in breaking the piece. Mounted upon the outer end of the spindle carrying the friction wheel is an index disc, which can be calibrated to read direct in ft.-lbs.

The whole machine is built on the lines of a high-class machine tool, thoroughly substantial and sufficiently simple to place its operation within the scope of the semi-skilled workman.

Consumption Figures in the Brass Foundry.

Some rather valuable figures have recently been obtained from a Continental source by Messrs. Alldays & Onions, Limited, Great Western Works, Birmingham, makers of the Charlier rolling furnace, respecting consumptions and melting losses in furnaces of this type. The figures have been selected by the well-known French metallurgist, Monsieur G. Espagne, from the results of the many tests he has carried out, and though in certain cases they appear to be contradictory, any information which throws further light on the subject of melting costs will probably be welcomed in the progressive foundry. For the benefit of those who are not acquainted with the type it may be explained that the Charlier furnace is of drum-shaped construction, lined with refractory material, and mounted on trunnions. It is suitable for either oil- or gas-firing, and the burner is arranged to play through one of the trunnions direct into the melting chamber. No crucibles are employed, and pouring is effected by tilting.

The following figures are the results of tests carried out at an establishment in Hayange (Alsace)—"Les Petits Fils de François Wendel et Cie" :—

Number of melt.	1	2	3
Metal	Gunmetal	Gunmetal	Gunmetal swarf
Weight of charge	706 lbs.	706 lbs.	353 lbs.
Time	57 min.	38 min.	28 min.
Consumption (oil)	9.46 gal.	8.36 gal.	3.74 gal.
Consumption : melting ratio	13.4%	11.87%	10.6%

The question of melting losses is a point which has been frequently raised in discussing performances of this type of furnace, in view of the fact that no crucible is employed. The following two tests, carried out in the foundry of a large French railway works, have a direct bearing on this point :—

1st.—Gunmetal.

Theoretical Composition.—Copper, 82 per cent. ; tin, 15 per cent. ; zinc, 3 per cent.

Analysis of the Metal Poured.—Copper, 81.41 per cent. ; tin, 15.357 per cent. ; zinc, 3.062 per cent. ; lead, 0.171 per cent.

Charged in Furnace.—Old copper, 541 lbs. ; tin, 99 lbs. ; zinc, 20 lbs.

Metal poured, 645 lbs.

Melting loss, 2¼ per cent.

2nd.—Gunmetal.

Theoretical Composition.—Copper, 87 per cent. ; tin, 10 per cent. ; zinc, 3 per cent.

Analysis of Metal Poured.—Copper, 87 per cent. ; tin, 10,097 per cent. ; zinc, 2.775 per cent. ; lead, 0.128 per cent.

Charged in Furnace.—Old copper, 574 lbs. ; tin, 66 lbs. ; zinc, 20 lbs.

Metal poured, 647 lbs.

Melting loss, 2 per cent.

The excess of Sn and Pb in the metal poured resulted from the zinc scrap employed, which contained a certain amount of solder. The makers of the Charlier furnace point out, however, that it is neither in the interests of foundry nor furnace builder to affirm that melting losses in that furnace are invariably as low as the figures above quoted.

OBJECTIONS TO LEDEBUR METHOD FOR OXYGEN IN STEEL.—A new publication of the Bureau of Standards, Scientific Paper No. 350, "Equilibrium Conditions in the System Carbon, Iron Oxide, etc., in Relation to the Ledebur Method for Oxygen in Steel," shows that mixtures of iron oxide and Acheson graphite are not, and mixtures of iron oxide with "cemented" iron or white iron (annealed or unannealed) are reduced at 900 deg. C. by the carbon in them when hydrogen is passed over them at rates of 2 litres per hour or faster. Because of these facts it is probably impossible to determine by the Ledebur method more than 75 per cent. of the oxygen present in steels as ferrous oxide. The effect of rate of passage of hydrogen on the Ledebur oxygen content of certain steels is shown.

NICKEL-IRON ACCUMULATORS.—Arrangements have been made by Batteries, Limited, Redditch, to manufacture in this country the nickel-iron-alkaline electric accumulator for which Dr. V. Jungner, a Swede, took out his first patent in 1899, and which began to be manufactured on a large scale by a Swedish company about eight years ago. The active material of the positive electrode is nickel hydroxide, mixed with other ingredients to increase the conductivity. This composition is formed into briquettes which are fed between two inactive perforated nickelled steel strips. These strips are cut up into suitable sizes, folded together, and fitted into a steel frame, the complete electrode being then put through a rolling process to ensure perfect contact between the active material and the steel strips. At the same time grooves are formed on the plate to keep the Para rubber insulators in position. The negative electrodes are constructed in the same way, the active material being iron oxide specially prepared and mixed with other materials to prevent self-discharge of the cell. The assembled positive and negative plates are immersed in a solution consisting chiefly of potassium hydrate, contained in a steel cell with brazed joints. The batteries are made in two types, one for a normal slow discharge in eight hours, and the other for rapid discharge in four hours. The average working voltage is 1.2 volt. ; it drops slightly during the first 15 minutes of discharge, and then remains practically constant till the cell is completely discharged.

Trade Talk.

THE London and North-Western and the Great Central Railway Companies propose experimenting with locomotives using oil fuel.

THE SCIENTIFIC METALS COMPANY, LIMITED, have now resumed occupation of their former offices at Imperial House, Kingsway, W.C.2.

MESSRS. A. A. NORTON & COMPANY have established works at Tivedale, Tipton, Staffs., for the manufacture of bedstead parts and fittings.

ARMSTRONG & MAIN, LIMITED, have removed from 3, Blenheim Street, New Bond Street, W.1, to Australia House, Strand, W.C.2.

A BRITISH CHAMBER OF COMMERCE has been established in Vienna at 1, Giselastrasse 7. Mr. A. G. Hamilton has been appointed secretary.

J. BLAKEBOROUGH & SONS, LIMITED, Woodhouse Works, Brighouse, have opened a London office at Kingsway House, Kingsway, London, W.C.2.

CUIRASS PRODUCTS, LIMITED, manufacturers of anti-rust paint, liquid proofing for damp walls, etc., have removed to 69, Victoria Street, Westminster, S.W.1.

THE SECURITY FOUNDRY COMPANY, LIMITED, are laying down a works in Oldbury Road, Smethwick, for the production of general castings and finished parts.

GEORGE CRADOCK & COMPANY, LIMITED, of Wakefield, have acquired nine acres of land in Vancouver, B.C., on which they propose to establish branch works.

MESSRS. E. LLOYD & COMPANY, tinplate and metal merchants, have removed from 85, Gracechurch Street, to Balfour House, 119-125, Finsbury Pavement, London, E.C.2.

R. & W. HAWTHORN, LESLIE & COMPANY, LIMITED, have completed another 14-in. standard locomotive, this being to the order of Cammell, Laird & Company, Limited.

THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH announces that a licence has been issued by the Board of Trade to the British Refractories Research Association.

THE new Northburn steel works of the Scottish Iron and Steel Company, Limited, are now in operation, and are proving of great value to the company in the supply of steel billets and slabs.

IN consequence of the retirement of Mr. A. P. Trotter, Handcock, Dykes & Trotter, consulting engineers, 11, Victoria Street, Westminster, S.W.1, will in future be known as Handcock & Dykes.

PALMERS SHIPBUILDING & IRON COMPANY, LIMITED, have purchased over 200 acres of land in the vicinity of Monkton, near Jarrow, on which it is proposed to erect new works and houses for workmen.

MESSRS. CARTERS, 3 and 4, Lothbury, London, E.C.2, have been appointed sole agents in the United Kingdom for the sale of the products of the Skoda Steel Works, at Pilsen, Czecho-Slovakia.

WM. BEARDMORE & COMPANY, LIMITED, have received an order from the London & North-Western Railway Company to build a number of powerful engines. The locomotives will be constructed at the company's Dalmuir Works.

THE collapse of a furnace lining at the blast furnaces belonging to the Ebbw Vale Steel, Iron and Coal Company, Limited, has resulted in the death of one man and injury to two others. The furnace was being re-lined at the time.

AUTOMATIC AND ELECTRIC FURNACES, LIMITED, 281-283, Gray's Inn Road, London, W.C.1, have appointed Messrs. F Hiorth & Sons, Josefinegade 13, Christiania, their agents for Norway and Denmark for Wild-Barfield electric furnaces.

SIR WM ARROL & COMPANY, LIMITED, have enlarged the scope of their activities by opening up a reinforced concrete department, by the acquisition of the business of Morrison & Mason, Limited, and by the formation of a general contracting department.

E. G. WRIGLEY & COMPANY, LIMITED, who recently purchased a controlling interest in Holcroft's Steel Foundry, Limited, is now effecting close inter-working arrangements with J. Tylor & Sons, Limited, and with Sir William Angus Sanderson & Company, Limited.

THE BRITISH THOMSON-HOUSTON COMPANY, LIMITED, are responsible for a statement to the effect that electric-lamp manufacturers, owing to the extended adoption of mass production methods, are experiencing no difficulty in satisfying the present home demand, and the importation of bulbs has ceased.

IN order to provide for the constant expansion of their business, Henry Rossell & Company, Limited, Waverley Works, Sheffield, have started the erection of a modern steel works on land at Blackburn Meadows, which they acquired some time ago. These will be occupied in addition to the present works.

THERE has been considerable delay in the delivery of the plant for the new power-station at Horden of the Waste Heat and Gas Electrical Generating Stations, Limited, and it is not expected that it will be completed and ready for operation until the end of the half-year. The new generating station at Weardale has been run satisfactorily but it is not yet in continuous operation.

THE sum of £25,000 has been allotted from the Professor Sir William Ramsay Memorial Fund towards the erection of a Ramsay Memorial Laboratory of Chemical Engineering on a site which the Senate of the University of London has undertaken to provide. The total sum required for the building and equipment is £50,000, and it is proposed to close the financial scheme in June next.

BRITISH ironmasters have recently been discussing with the representatives of a commercial delegation from Brazil the possibilities of obtaining larger supplies of ore from that country. The idea of the Brazilians is that the steamers taking the ore to England might return with coal and coke suitable for the iron and steel industry in Brazil. The Itabiri Company propose to establish a line of steamers designed for the ocean transport of ore.

Under a recent agreement, Hadfields, Limited, have acquired 166,666 8 per cent. cumulative participating preference shares of £1, and 83,334 ordinary shares of £1 each, in Harper Bean, Limited, in exchange for 166,666 ordinary shares of Hadfields, Limited, with the right to nominate a director, and Major Clerke has been elected to this office. For this purpose it is proposed to increase the capital of Hadfields by £500,000, leaving £333,334 to be issued.

THE directors of Baldwins, Limited, state that the arrangements for the purchase by Messrs. Sperling & Company of the ordinary shares of Baldwins, Limited, have been completed. The shareholders have accepted the offer of £3 per share practically en bloc, the requisite 51 per cent. having thus been exceeded. Messrs. Sperling, it is announced, were acting in the deal for the Northumberland Shipbuilding Company, Limited.

THE headquarters office of the Central Commercial Department of Sir W. G. Armstrong, Whitworth & Company, Limited, has been removed to 3, Woodstock Street, Oxford Street, W.1. The company are preparing to add civil engineering and public works contracting on a large scale to their extensive enterprise. We understand that this civil engineering department has now been formed, under the control of Mr. R. H. Mackenzie, and will commence operations immediately.

LAZARD BROS. & COMPANY, LIMITED, have placed privately on the basis of a yield to redemption of £8 3s. per cent. an amount of £1,380,000 7½ per cent. three year notes of Sir W. G. Armstrong, Whitworth & Company, Limited. These notes are issued at the request of the Belgian Government in connection with an order for locomotive engines, and the Government has undertaken to provide Sir W. G. Armstrong, Whitworth & Company, Limited, with funds to meet both principal and interest.

SOUTHWARK, the second of the Boroughs of London to embrace the ideals of the Industrial League and Council, has formed a local branch of the League. A meeting was convened in Southwark Town Hall, on Thursday, March 25, for the purpose of considering the aims and objects of the Industrial League and Council, and if the same were approved, inaugurate a branch of the League in that borough forthwith. Special representatives were invited to attend from the League in order to place the claims of the organisation before the meeting, at the close of which it was unanimously decided to inaugurate a Branch at Southwark.

AT the annual meeting of the Machinery Users' Association, Sir Algernon Firth was re-elected as president, with Lord Aberconway, Lord Emmott, Lord Colwyn, Sir Lindsay Wood, Sir Alfred Mond, M.P., Sir James Heath, and Mr. Lewis Evans as vice-presidents. In reviewing the year's work the President said that no fewer than 280 firms had joined the Association during the year. The Association had come to an arrangement with the Federation of British Industries whereby the former acted as the rating and valuation department of the latter, and that co-operation was of mutual advantage. The committee had redrafted a Bill which sought to give English and Welsh machinery users the same measure of exemption from rating as was enjoyed by Scottish manufacturers. The meeting approved the Bill as redrafted.

According to M. Gelphe, who is a member of the Swiss Parliament, and a civil engineer, the present prospects of holding open Switzerland's sole natural access to the Ocean are not very promising. According to the Peace Treaty regulations, concerning the navigation of the Rhine, France is allowed the exclusive and unlimited right of using the hydraulic resources of the river from Basle to Lauterburg, a distance of 183 kms. (113 miles). The writer maintains that, looked at from an unprejudiced point of view, there can be no two opinions on the fact that the utilisation of the Upper Rhine on the section in question, for purposes of power and navigation, can only be achieved at the expense of the river's importance and efficiency as a great highway of European traffic. Therefore, it is in the interest of the whole civilised world that the waterway of the Rhine should be fully developed between Basle and Rotterdam for through navigation, without impediments and locks.

IN their annual report the directors of Alfred Hickman, Limited, state that they have carried through a scheme of amalgamation with Lloyd's Ironstone Company, Limited, owning blast furnaces and large ironstone and limestone properties in Northamptonshire, whereby they have acquired the whole of the share capital of that company, the shareholders in Lloyd's Ironstone Company taking shares in Alfred Hickman, Limited, in part payment for their holding in Lloyd's Ironstone Company. By this transaction a considerable addition has been made to the existing large reserves of raw materials owned by the company. Mr. S. J. Lloyd and Mr. A Crawford, directors of Lloyd's Ironstone Company, join the board of Alfred Hickman, Limited. The profit-sharing scheme sanctioned in June last has been inaugurated, and up to the end of the year 20,506 participating preference shares had been taken up by the employés of the company. The issue remains open for subscription until June 30 next. It is proposed to call up the balance of 10s. per share due on partly-paid shares in two instalments of 5s. each.

THE second annual meeting of the Scottish Federation of Iron and Steel Merchants' Associations has been held in Glasgow, under the presidency of Mr. W. H. Kidston. In the course of the annual report the council stated that in the revision of the prices by makers at the date of delivery the fluctuation of costs did not appear to operate in favour of the merchants in the event of a fall, but it was understood that the makers had now provided for fluctuations of costs operating in favour of the makers and merchants as these costs increase or fall. The selling policy of makers, as to quoting to merchants where quotations had already been sent to consumers direct, had been under the consideration of the council, but the representations of the federation to makers had not received the consideration expected, and this policy the council much regretted. On the motion of the chairman, seconded by Mr. Irving, the report and financial statement were unanimously adopted. The executive council for the year was elected, and a general conference on the questions of interest affecting merchants took place.

SIR GEORGE B. HUNTER presided at a meeting of Swan, Hunter & Wigham Richardson, Limited, held for the purpose of passing resolutions to increase the capital of the company and to amend certain of the articles of association. The chairman said they did not propose at the present time to issue any shares to the public. He would like some arrangement whereby they could enable and induce members of their staff and their workmen to become shareholders. That, however, would be a private issue, and they did not require any further capital, so far as their present plans were concerned. They had found it desirable and necessary to acquire the Blaydon Ironworks, and, jointly with Sir William Beardmore, of Glasgow, the shares of the Glasgow Iron & Steel Company, Limited. In each case the reason for the purchase was to provide materials for carrying on the company's work. The difficulty on the Tyne, continued Sir George, was chiefly concerned with transport. The steelworks could make what the shipbuilders needed, but they could not transport it by rail on account of the congestion. Steel was lying at the steelworks, and could not be sent to shipyards. They might in the future require additional capital, but so far they had been able to make their purchases out of their reserves. When they did spend money on extensions it would be when costs were lower

Personal.

MR. C. A. BENDIX has joined the board of the Bengal Iron Company, Limited.

THE late Mr. W. H. Hollingdale, secretary of Newport Metal Exchange, left estate valued at £16,058 gross.

THE late Mr. R. J. Wales, joint assistant managing director of T. W. Ward, Limited, left estate valued at £26,251.

MR. E. ROBINSON and Mr. J. Mosley are the first directors of Eber Robinson & Company, Limited, engineers, Keighley.

MR. J. W. BEATTIE, chief engineer under the Blaenavon Company, Limited, has been appointed works manager of the company.

SIR GEORGE NOBLE, BART., of Sir W. G. Armstrong, Whitworth & Company, Limited, has returned to this country from the States.

THE late Mr. E. Perrin, a director of the Isle of Man Mining Company, Limited, left estate of the gross value of £112,017, with net personalty £109,270.

THE late Mr. G. F. Newman, a director of Wm. Newman & Sons, Limited, brassfounders, has left property of the value of £28,032, with net personalty £27,568.

SIR JOHN HUNTER, Dalmarnock Ironworks, Glasgow, and Mr. Harry Potter, one of the original vendors, have been elected directors of the Rivet, Bolt & Nut Company, Limited.

MR. W. T. LAYTON, director of the National Federation of Iron and Steel Manufacturers, has just been granted a year's leave of absence to take up organisation work in connection with the international financial conference, as an official of the economic section of the League of Nations.

MR. R. P. SMITH, assistant manager to the Lanarkshire Steel Company, Limited, has been entertained at a complimentary dinner on the occasion of his leaving the works after 12½ years' service. Mr. Smith, after

MOULDING MACHINES

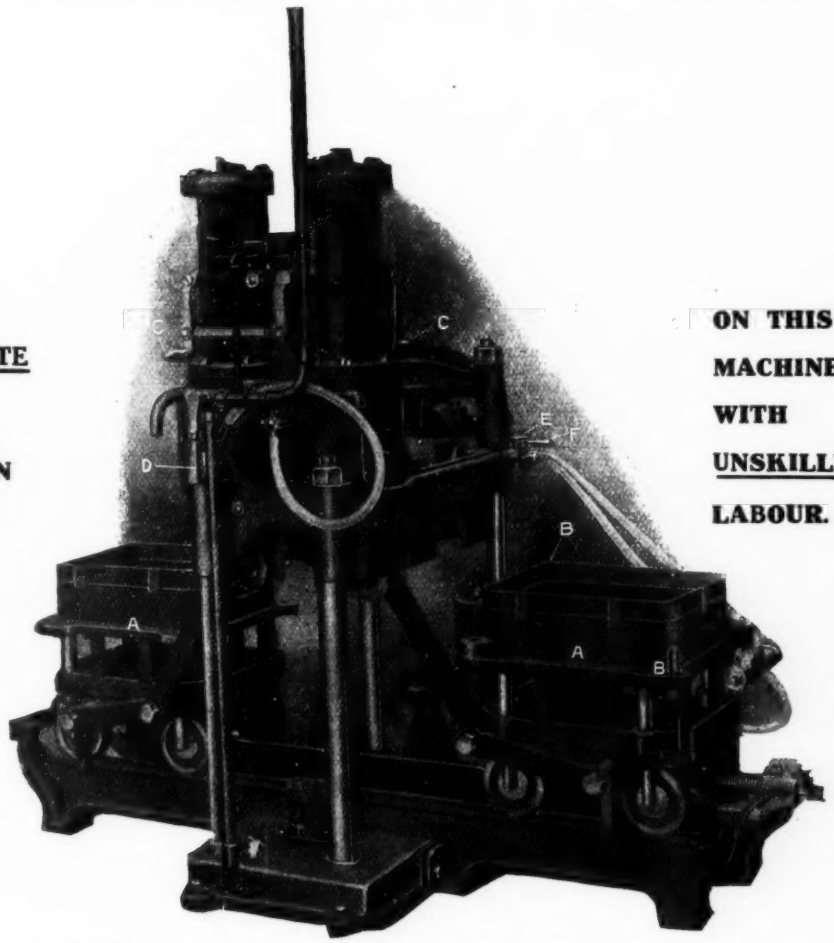
OF EVERY DESCRIPTION.

Pneumatic, Hydraulic, Jar Ramming, & Hand Power.

Type "A" Duplex Machine for Pneumatic Power.

Fitted with self-adjusting Rammer Head which accommodates itself to any varying depth of pattern.

OVER 50 COMPLETE MOULDS PER HOUR HAVE BEEN PRODUCED



ON THIS MACHINE WITH UNSKILLED LABOUR.

One of many that we have installed in various Munition Work Centres.

JAMES EVANS & CO., BRITANNIA WORKS, BLACKFRIARS, MANCHESTER.

a visit to America, joins the staff of David Colville & Sons, Limited, Dalzell Steel and Iron Works, Motherwell.

MR. L. R. TURNBULL, chairman of the Penarth Pontoon, Slipway and Ship-Repairing Company, Limited, has decided to retire, and has been the recipient of a presentation from his colleagues. The directors have elected Mr. H. O. King to a seat on the board. Mr. Joseph Rose has been appointed to fill the vacancy caused by the retirement of Mr. W. J. Tillett.

MR. H. BREARLEY, of Sheffield, has been awarded the Bessemer Medal by the council of the Iron and Steel Institute. Mr. Brearley is a director of Brown, Bayley's Steel Works, Limited, of Sheffield, and his previous appointment was that of head of the Brown-Firth Research Laboratory. He has contributed many papers on metallurgical subjects at the meetings of the Iron and Steel Institute, and has published standard works on the heat treatment of steel.

Deaths.

MR. WILSON WORSDELL, who for twenty years controlled and directed the locomotive construction of the North-Eastern Railway, died on April 14, at South Ascot, Berkshire, aged 70 years.

MR. D. RANKINE, whose death is announced at the age of 82 years, was the senior partner of Messrs. D. R. and G. Rankine, mining and consulting engineers, West George Street, Glasgow. He was one of the mineral referees appointed by the Government in Scotland since 1909.

The death has taken place in his 78th year of Mr. R. Thomas, J.P., of Field House, Stafford Road, Bloxwich. He was a member of the firm of Messrs. G. & R. Thomas, ironmasters, and was also prominently identified with the mining industry, until the coal measures in the Bloxwich area were worked out.

THE death is announced of Mr. T. Black, of Tynemouth, a gentleman well known in the iron industry of the port. The deceased gentleman, who was 69 years of age, was a native of Spennymoor, and when a lad began his career as a stock-taker with the Weardale Iron and Coal Company and the Tudhoe Ironworks. His aptitude and perseverance in gaining a thorough insight into the manufacture of iron and steel quickly brought him under the notice of his employers, and advancing step by step he was eventually appointed to the position of works' manager. When Lord Furness took over the works and collieries Mr. Black severed his connection with the Weardale Company, and as an iron and steel merchant conducted a flourishing business in Newcastle.

MR. A. HOLMES, managing director of C. D. Holmes & Company, Limited, engineers, Hull, died after a brief illness on March 31 at his residence at Elloughton. He was the son of Mr. S. H. Holmes, and became associated with his uncle, Mr. C. D. Holmes, in the engineering trade, being elected managing director when the extensive business was converted into a limited liability company. As a member of the Hull Iron Trades Employers' Association, and in other ways, he held an influential position in engineering circles.

MR. H. S. B. BRINDLEY has died at his residence, 49, Ashley Gardens, S.W.1. The deceased gentleman, who was in his 53rd year, was the son of Mr. G. S. Brindley, of Birmingham, engineer and mechanical instructor at the Imperial College of Engineering, Tokyo. He was placed in the Japanese Imperial College of Engineering, which afterwards became the Tokyo University. After serving with several British firms, he returned to Japan in 1895 as consulting engineer and technical representative, opening up engineering business relations between British firms and the Japanese Government. In 1907 he returned to England, and started as a consulting engineer in Westminster. When the war broke out he devoted his whole energies to the production of shells, and was appointed a K.B.E. in the honours list just issued.

COLONEL SIR CHARLES ALLEN, V.D., chairman of H. Bessemer & Company, Limited, Sheffield, and of the Ebbw Vale Steel, Iron and Coal Company, Limited, died at Folkestone in his sixty-ninth year. In March of last year he underwent a serious operation, from the effects of which he never fully recovered. Sir Charles Allen was born in 1851, at Camden Town, London, N.W. His father was the late Mr. W. D. Allen, brother-in-law of Sir Henry Bessemer, and the perfecter of the latter's invention of the steel-making process which bears his name. Mr. W. D. Allen founded the firm of Henry Bessemer & Company, Limited, Sheffield, one of the most prominent in the steel trade of the city. Sir Charles Allen was educated at the Commercial College, Halifax, and in Germany. He may be said to have been connected with the manufacture of Bessemer steel all his life, for as a young man he was present at the first experiment made. He joined the firm of Henry Bessemer and Company when a young man, and was a director for many years, succeeding, as chairman, his brother, the late Mr. Harry Allen, about fifteen years ago. Under his guidance the firm has enjoyed a period of practically unvarying prosperity, being regarded as one of the steadiest concerns in Sheffield. Doubtless to this same circumstance is attributable its long immunity from anything in the nature of serious labour troubles. As a near relative of Sir Henry Bessemer, it was only fitting that Sir Charles Allen should have been prominently identified with the founding of the memorial to the great inventor. This memorial took the form of the Bessemer Laboratory in the Imperial College of Science and Technology, London, which was handed over to the governing body on January 30, 1912. Sir Charles Allen was also for many years a director of the Ebbw Vale Company and the Carlton Main Colliery Company, and was in every way a conspicuous figure in the commercial world. Other appointments which he held were those of vice-chairman of the Sheffield and Hallamshire Bank, Limited, and chairman of the Charbonnages de Rodey, France, and director of the British Coalite Company, Limited. Sir Charles received his knighthood from the late King Edward on June 25, 1908, his name being included in the list of birthday honours for that year. His honour was, of course, regarded as a special recognition of the work he had rendered to the Volunteer cause, and in the creation of the new Territorial Army scheme.

Applications for Patents.

Ballantine, W. B. Refining metals and alloys. 5,811. February 26.

Boyer, J. G. Burners for furnaces and kilns. 9,241. March 30.

Coles, S. O. Cowper-. Process for electro-deposition of alloys of copper and zinc. 5,549. February 24.

Coles, S. O. Cowper-. Process for production of metallic parts. 5,703. February 25.

Electrolytic Zinc Company. Electrolytic treatment of ores containing zinc, etc. 9,445. April 1. (Australia, April 4, 1919.)

Cosgrave, S. A. Production of malleable iron castings 5,427. February 23.

Gilbertson & Company, W. Foundry ladles, etc. 5,812. February 26.

Lambot, J. Rocking furnaces. 9,297. March 31. (France, April 3, 1919.)

Lambot, J. Oil-fired furnaces. 9,298. March 31. (France, April 3, 1919.)

Lambot, J. Rotary hearths for furnaces. 9,300. March 31. (France, April 3, 1919.)

Lange, K. Rivet forge. 5,753. February 25. (Germany, December 24, 1918.)

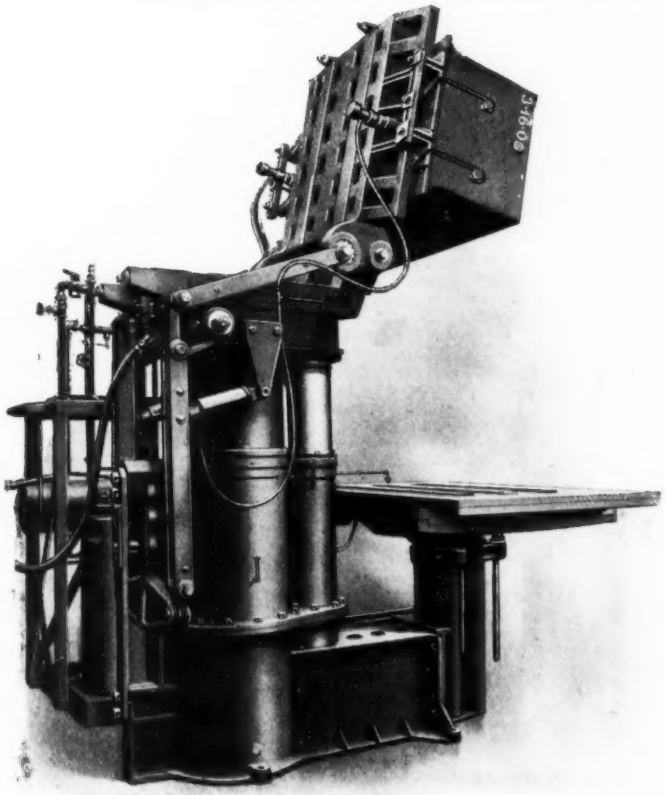
Scott, R. Machinery. 8,375. March 22.

MACNAB & CO.

TABOR PATENTS.

Patent Combination Shockless Jar Ramming Power Roll-over and Pattern Drawing Moulding Machine.

Suitable for the most economical production of any repetition work, from the smallest up to a load of 12,000 lbs. at 100 lbs. air pressure, covered by a range of five machines.



Mould having been rammed, box and pattern in act of being rolled over on to levelling table on other side of machine.

Jar rams the box in less than one minute.

Rolls the mould over, draws and raps the pattern.

Rolls the pattern back ready for the next box.

COMPLETE MECHANICAL OPERATIONS OF THE MACHINE NOT EXCEEDING FOUR MINUTES.

56/8, Eagle Street, Southampton Row, London, W.C.1.

New Companies.

Engineering Trust, Limited.—Capital £100,000 in £1 shares.

Drakeson Recorders, Limited, Engineers.—Capital £50,000 in £1 shares.

South Wales Silica Company, Limited.—Capital £10,000 in £1 shares.

Pelabon, Limited.—Capital £250,000 in £1 shares, to carry on the business of engineers.

Wyre Motors, Limited.—Capital £10,000 in £1 shares. Registered office: Copse Road, Fleetwood.

Joseph J. Armfield & Company, Limited, Ironfounders.—Capital £30,000 in £1 shares.

Taylor, Hunter & Company, Limited.—Capital £5,000 in £1 shares, to carry on the business of engineers.

C. T. Bowring & Company (West Coast America), Limited, Machinery Manufacturers.—Capital £10,000 in £1 shares.

Talbot-Stead Tube Company, Limited. — Capital £500,000 in £1 shares. Registered office: Green Lane, Wallsall.

E. Tonks & Sons, Limited.—Capital £50,000 in £1 shares, to carry on the business of manufacturers of locks, etc.

A1 Engineering Company, Limited.—Capital £10,000 in £1 shares. Registered office: 5, Granby Street, Leicester.

Bower & Taylor, Limited (engineers).—Capital £5,000 in £1 shares. Registered office: 7-8, Great Winchester Street, E.C.

Wear Arc Welding Company, Limited.—Capital £5,000 in £1 shares. Registered office: South Dock, Sunderland.

Spearing Boiler Company, Limited.—Capital £50,000 in £1 shares. Registered office: 11, Queen Victoria Street, E.C.

Associated Electric Welders, Limited.—Capital £10,000 in £1 shares. Registered office: 29a, Victoria Street, Grimsby.

H. T. Hazzledine, Limited (engineers). — Capital £10,000 in £1 shares. Registered office: 5, Talbot Street, Nottingham.

Farnworth Engineering Company, Limited.—Capital £20,000 in £1 shares. Registered office: 21, Spring Gardens, Manchester.

Whessoe Foundry & Engineering Company, Limited. —Capital £200,000 in £1 shares. Registered office: 106, Cannon Street, E.C.

Pickersgill Bros., Limited, Engineers. — Capital £12,000 in £1 shares. Registered office: Rectory Ironworks, Keighley.

J. Hopkinson & Company, Limited.—Capital £600,000 in £1 shares (250,000 preference), to carry on the business of engineers.

Artofex Engineering Works, Limited. — Capital £10,000 in £1 shares. Registered office: 6 and 8, Pentonville Road, N.

Steel Slag Syndicate, Limited. — Capital £10,000. Directors: H. G. Keywood, and J. H. Beckett. Registered office: Leeds.

Charles Ray (Bedstead Plant), Limited.—Capital £4,000 in £1 shares. Registered office: 12, Cherry Street, Birmingham.

Scottish Welding & Steel Metal Company, Limited.—Capital £3,000 in £1 shares. Registered office: 129, Union Street, Aberdeen.

Super-Vice Engineering Company, Limited.—Capital £10,000 in 9,750 ordinary shares of £1, and 5,000 founders' shares of 1s.

Scottish Aluminium Company, Limited.—Capital £25,000 in £1 shares. Registered office: 150, Helen Street, Govan, Glasgow.

John Rogers, Limited.—Capital £80,000 in £1 shares, to carry on the business of boiler makers. Registered office: Bute Docks, Cardiff.

Eagle Brass Foundry Company, Limited.—Capital £5,000 in £1 shares. Registered office: 29, Clowes Street, Chapel Street, Salford.

Associated Metal Supply Company, Limited.—Capital £25,000 in £1 shares (10,000 preference). Registered office: 21, Old Kent Road, S.E.

London Lubricants (1920), Limited.—Capital £100,000 in £1 shares (25,000 preference). Registered office: 628, Old Ford Road, Bow, E.3.

H. Palin, Limited.—Capital £10,000 in £1 shares, to carry on the business of engineers. Registered office: 164, Mansfield Road, Derby.

Service Steel & Engineering Company, Limited.—Capital £2,000 in £1 shares. Registered office: 55, Ditchingham Street, Sheffield.

Associated Metal Supply Company, Limited.—Capital £25,000 in £1 shares (10,000 preference). Registered office: 21, Old Kent Road, S.E.

Ferrons, Limited.—Capital £30,000 in £1 shares, to carry on the business of ironfounders. Registered office: Peel Street, Bridgeton, Glasgow.

Drum Engineering Company, Limited. — Capital £20,000 in £1 shares (5,000 preference). Registered office: 28, Humboldt Street, Bradford.

Riglite Manufacturing Company, Limited, Engineers. —Capital £5,000 in £1 shares. Registered office: 18, Cowleaze Road, Kingston-on-Thames.

Stannaries Engineering Company, Limited.—Capital £10,000 in £1 shares. Registered office: 48 and 50, Waterloo Street, Camberwell Green, S.E.

Callim Metallurgical Company, Limited.—Capital £10,500 in £1 shares (10,000 cumulative preference). Registered office: 92, Banner Street, E.C.

Gwynne's Engineering Company, Limited.—Capital £600,000 in £1 shares. Registered office: Hammersmith Iron Works, Crisp Road, Hammersmith.

Thomas Birch, Limited.—Capital £5,000 in £1 shares, to carry on the business of brassfounders. Registered office: 45, Molesworth Street, Rochdale.

United Brassfounders & Engineers (1920), Limited.—Capital £1,500,000 in £1 shares. Registered office: Empress Foundry, Cornbrook, Manchester.

Middlesbrough Transport & Engineering Company, Limited.—Capital £10,000 in £1 shares. Registered office: 44, Linthorpe Road, Middlesbrough.

Monmouth Shipbuilding Company, Limited.—Capital £200,000 in £1 shares (100,000 preference). Registered office: Basildo House, Moorgate Street, E.C.

W. J. L. Robinson, Limited.—Capital £15,000 in £1 shares, to carry on the business of iron merchants, etc. Registered office: 20, James Street, Liverpool.

Harry Bairstow, Limited.—Capital £3,500 in £1 shares, to carry on the business of iron manufacturers. Registered office: Alice Street, Keighley, Yorks.

William H. Hulme & Sons, Limited.—Capital £15,000 in £1 shares, to carry on the business of engineers. Registered office: Halley Mill, Buckley, Rochdale.

Green & Smith, Limited.—Capital £15,000 in £1 shares, to carry on the business of engineers. Registered office: Albert Works, Meadow Lane, Leeds.

McLellan Engineering Company, Limited.—Capital £10,000. Directors: S. Marshall, T. W. Cunningham, and A. McLellan. Registered office: Spennymoor.

Etheridge & Cockerell, Limited.—Capital £10,000 in £1 shares, to carry on the business of engineers. Registered office: 10 and 12, Byward Street, E.C.3.

W. H. Pickering & Company, Limited, Engineers.—Capital £7,000 in £1 shares. Registered office: Soho Ironworks, South Street, Heywood, near Manchester.

Bartle Brothers, Limited.—Capital £25,000 in £1 shares, to carry on the business of engineers. Registered office: Basset Foundry, Carn Brea, S.O., Cornwall.

Woods, Jamieson & Company, Limited.—Capital £5,000 in £1 shares, to carry on the business of engineers. Registered office: 53a, Pulford Street, Pimlico, S.W.

H. J. Humphries & Cooper Smelting Corporation, Limited.—Capital £20,000 in £1 shares (15,000 preference). Registered office: 40, St. Peter's Street, St. Albans.

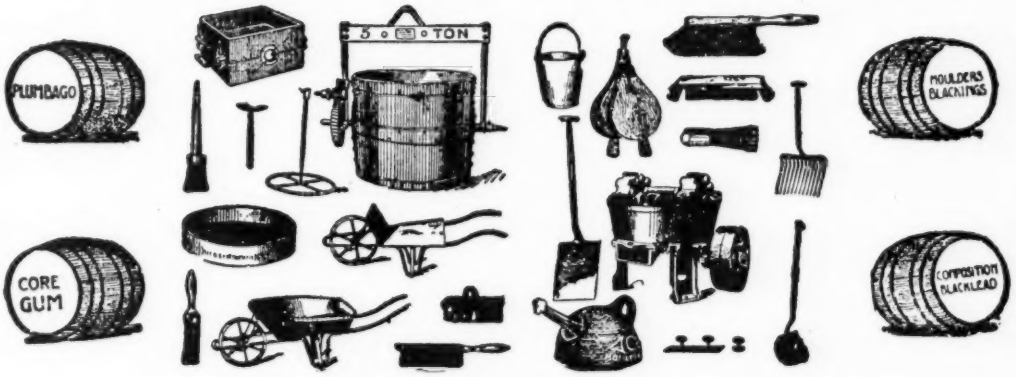
John H. Riddel, Limited.—Capital £10,000 in £1 shares, to carry on the business of iron and steel mer-

Telephone: 21, Pennistone. Telegrams: "Durrans, Pennistone."

Established 1863.

JAS. DURRANS & SONS,

Phœnix Works, Penistone, Near Sheffield.



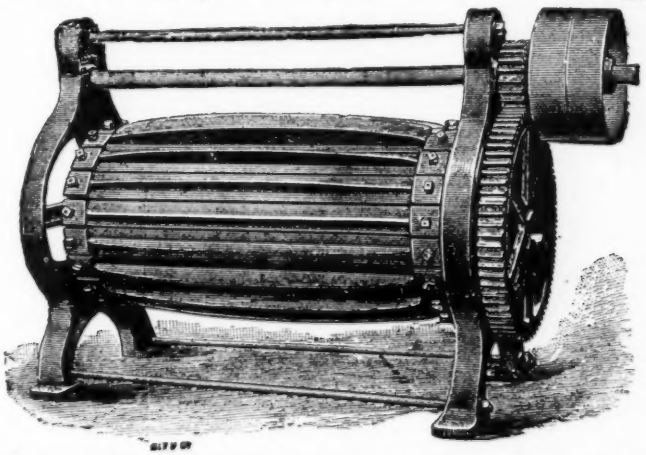
Manufacturers of all

FOUNDRY EQUIPMENTS

COMPOSITION BLACK LEAD, PLUMBAGO, CORE GUM, WHITE DUST & COAL DUST

Ladles, Cupolas, Fire Bricks, Gannister, Stone Flux, Loam and Sand Mills, Casting Cleaners, Studs, Chaplets, Pipe Nails, Sprigs, Brushes, Wire Brushes, Core Ropes, Bellows, Buckets, Spades, Forks, Riddles, Sieves, Barrows, Etc.

Improved Foundry Rattler or Fettling Drum.



These Machines are invaluable for a Foundry, doing a larger amount of work of a superior quality, in a much shorter time than can be done by hand, without skilled labour.

The following testimonial explains itself :—

"Dear Sirs,—We have been using your best Blacking for a large number of years, and always use it on our large Ingot Moulds, which, as you know, we have made up to 85 tons in weight.

Yours faithfully, THE BRIGHTSIDE FOUNDRY & ENGINEERING CO., LD.

chants, etc. Registered office: 40, St. Enoch Square, Glasgow.

Security Foundry Company, Limited. — Capital £10,000 in £1 shares, to take over the business carried on at Oldbury, Worcs., as the Security Manufacturing Company.

R. A. Munden & Company, Limited, Gas Furnace Manufacturers.—Capital £10,000 in £1 shares. Registered office: Dover Street Works, Dover Street, Coventry.

Thomas Walker & Sons (Tewkesbury), 1920, Limited.—Capital £8,000 in £1 shares, to carry on the business of engineers. Registered office:—Oldbury Road, Tewkesbury.

W. H. McKenzie, Limited.—Capital £2,500 in £1 shares (2,000 7½ per cent. cumulative preference). Registered office: Waverley Iron Works, Stone Street, Oldbury, Worcs.

Thomas Wilson & Sons (Swalwell), Limited.—Capital £20,000 in £1 shares, to carry on the business of brassfounders. First directors: T. Wilson, T. Wilson, jun., and R. R. Wilson.

Marchbank, Bainbridge & Stonehouse, Limited.—Capital £250,000 in £1 shares, to carry on the business of ironmasters. Registered office: Exchange Buildings, Newcastle-on-Tyne.

Williams of Sheffield, Limited.—Capital £10,000 in £1 shares, to carry on the business of manufacturers of steel, etc. Registered office: Wharncliffe Chambers, Bank Street, Sheffield.

John Baker & Sons, Limited.—Capital £20,000, to carry on the business of file manufacturers at Sheffield. First directors: T. Baker, J. K. Baker, T. F. Baker, and J. K. Baker, jun.

Andrew Gillespie & Sons, Limited.—Capital £35,000 in £1 shares, to carry on the business of mechanical engineers, etc. Registered office: 43, Smith Street, Kinning Park, Glasgow.

Barnes & Bell, Limited.—Capital £40,000 in £1 shares, to acquire the business of iron, steel, and machinery merchants. Registered office: 79, St. George's Place, Glasgow.

Thomas Sorby & Sons, Limited.—Capital £50,000 in £1 shares (5,000 cumulative preference participating ordinary and 45,000 deferred ordinary), to carry on the business of steel makers.

Selby Constructional & Gas Engineering Company, Limited.—Capital £15,000 in £1 shares. First directors: G. K. Dick and T. Heaton. Registered office: Crown Works, Selby, Yorks.

Campbell & Calderwood, Limited.—Capital £50,000 in £1 shares, to acquire and carry on the business of engineers and shipbuilders. Registered office: Soho Works, Murray Street, Paisley.

R. J. Richardson & Sons, Limited.—Capital £10,000 in £1 shares, to carry on the business of mechanical, electrical, and general engineers, etc. Registered office: Commercial Street, Birmingham.

Avon Foundry, Warwick, Limited.—Capital £10,000 in £1 shares, to take over the business of W. Bissell at Avon Street and Emscote Road, Warwick. Registered office: 8a, Castle Street, Warwick.

William Lee & Sons, Limited (agricultural machine manufacturers).—Capital £50,000 in £1 shares (25,000 preference). Registered office: Montrose Works, Calley-white Lane, Dronfield, near Sheffield.

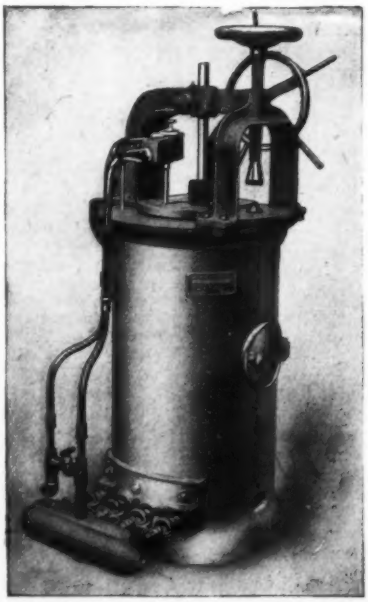
R. P. Boyd & Company, Limited.—Capital £10,000 in £1 shares, to carry on the business of manufacturing, electric and mechanical engineers, etc. Registered office: Hooper Street, Birmingham.

Ealing Park Foundry, Limited.—Capital £35,000 in £1 shares, to take over the business carried on by H. Shannon, at Junction Road, South Ealing. Registered office: Crisp Road, Hammersmith, W.6.

Alex. Anderson & Sons, Limited.—Capital £40,000 divided into 10,000 7½ per cent. cumulative preference and 30,000 ordinary shares, both of £1 each. Registered office: Carfin Works, Motherwell.

THE "REAL PRESSURE" DIE CASTING PLANTS.

Contractors to the War Office, Admiralty, Ministry of Munitions and Air Ministry.



DIE-CAST IT.

Magneto Parts, Ball Bearing Parts, Die-Cast with Steel Balls in complete. Bearings, Screw Threads, Gears, Accumulators, Grids, Wheels, Rings, etc., etc.

The only heat controlled die-casting plant on the world's market.

Pressure of 7 tons obtained.

Complete castings up to 40-lbs. white-metal alloys can be made in one operation.

Interchangeable nozzles for different sizes of castings.

Interchangeable pots.

For the production of "dead-size die castings" in tin, lead, zinc and aluminium alloys and all white metals.

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MONOMETER MANUFACTURING Co.

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WE SUPPLY **THE** LEADING FIRMS IN THE TRADE WITH

FOUNDRY BLACKINGS

OF ALL KINDS

COAL DUST, CHARCOAL, PLUMBAGO and BLACK-LEAD CORE GUMS and all Foundry Requisites, and have done so since 1831.

I. & I. WALKER, EFFINGHAM MILLS, ROTHERHAM.

Our Specialite is Studying Special Requirements.

KINDLY HAND US YOUR ENQUIRIES.

The Mastery

of the Air.

TRADE SIROCCO MARK

FANS

SEND US YOUR ENQUIRIES FOR

are always successful in the struggle for the Mastery of the Air

Ventilation of Ships, Buildings and Mines, Induced Draught on Boilers, Dust Removal, High Pressure Fans for Forge Fires and Cupolas, Air Washers for Cooling and Purifying the Air, Fans for Removing Fumes or Steam, Steam Heater Units for Heating Factories and Workshops.

Davidson & Co., Limited, *Sirocco Works,* **BELFAST.**

GANISTER, CUPOLA BLOCKS, FIRE BRICKS,

FIRE CLAY.

Silica Bricks, Tuyeres, Stoppers, Nozzles, &c.

STEEL MOULDERS' COMPOSITION, SILICA CEMENT.

J. GRAYSON LOWOOD & Co., Ltd.,

DEEPCAR nr. SHEFFIELD.

Telegrams: "LOWOOD, DEEPCAR."

MONTHLY PRICE LIST.

The undermentioned prices, unless otherwise specified, are those obtaining at the commencement of the current month.

Pig-Iron.

	Home £ s. d.
Hematite—	
East Coast Mixed Nos.	13 0 0
East Coast No. 1	13 2 6
West Coast Mixed Nos.	13 15 0
Scottish Mixed Nos.	13 0 0
Welsh Mixed Nos.	13 0 0
Cleveland—	
No. 1	10 12 6
No. 3 foundry G.M.B.	10 0 0
No. 4 foundry	10 0 0
No. 4 forge	10 0 0
Basic	10 10 0
Derbyshire, Leices., and Notts—	
No. 4 forge	10 8 6
No. 3 foundry	10 13 6
No. 2 foundry	10 15 6
No. 1 foundry	10 17 6
Basic	10 10 0
Northamptonshire—	
No. 4 forge	9 15 0
No. 4 foundry	9 16 6
No. 3 foundry	9 17 6
No. 2 foundry	9 19 0
No. 1 foundry	10 0 0
Basic	10 7 6
South Staffordshire, Shropshire and Worcestershire—	
Part-mine forge	11 2 6
Part-mine foundry	11 5 0
Common Staffs.	9 15 0
All-mine forge	11 15 0
All-mine foundry	12 0 0
Warm-air forge	12 12 6
Warm-air foundry	13 2 6
Cold blast	15 15 0
Basic	10 10 0
Scottish—	
Foundry, No. 3	12 10 0
Delivered in Manchester—	
*Derbyshire, No. 3	—
*Cleveland, No. 3	—
*Scottish, No. 3	—
* Merchant prices.	
Delivered in Sheffield—	
East Coast hematite	—
Derbyshire basic	—
Lincolnshire basic	—
Do. No. 3 foundry	—
Do. forge	—

High-Speed Tool Steel.

	s. d.
Finished bars, 14 per cent. Tungsten	3 2
Finished bars, 18 per cent. Tungsten. Per lb. delivered buyers' works.	3 9
Extras—	
Rounds and squares 3 in. to 8 in. inclusive	4d. per lb.
Rounds and squares under ½ in. to ¾ in.	3d. ,,
Flats under 1 in. by ¾ in. to ½ in. by ¾ in., and all sizes over four times 3 in width and over thickness	3d. ,,
Bevels of approved sizes and sections	6d. ,,
If in Coils	3d. ,,
Packing	4s. per cwt
Bars cut to length	10% extra
Scrap from High-Speed Tool Steel— Scrap pieces, 5d. Turnings and Swarf, 3d. Per lb. net, d/d steel-makers' works.	

Ferro-Alloys.

Ferro-Titanium—23/25%, Ti. carbonless, 1/10.
Ferro-Tungsten.—75/80%, 3/3.
Ferro-Molybdenum.—70/80%, Mo., 12/-.
Ferro-Vanadium.—35/40%, Va., 56/-.
Metallic-Manganese.—98/99%, carbonless, 3/6. (All per lb.).
Ferro-Phosphorus—20/25%, P. £52 10 0.
Ferro-Chrome.—4/6%, car., £42 10 0.
Ferro-Chrome.—6/8%, car., £42 10 0.
Ferro-Chrome.—8/10%, car., £42 10 0.
Ferro-Chrome.—Specially refined, basis 60% chr., max. 2% car., £98 0 0.
Ferro-Silicon.—45/50% Si., £26 0 0 d/d. at Sheffield Steelworks.
Ferro-Manganese.—80%, £35 0 0. loose, £36 0 0. packed. Export £10, according to destination. (All per ton.)

Copper.

	£ s. d.	£ s. d.
Standard cash	105 0 0	105 2 6
Three months	107 10 0	107 15 0
Electrolytic	111 0 0	113 0 0
Tough	108 0 0	109 0 0
Best selected	109 0 0	110 0 0
Sheets	163 0 0	—
India	165 0 0	170 0 0
American electrolytic spot	111 0 0	—
Do. June	111 10 0	112 0 0
Official average price cash, Mar.		109 11 10 15/16
Do. Three months, Mar.		112 13 11 1/4
Do. Settlement, Mar.		109 11 11 1/2
Do. Electro' Mar.		119 14 4 3/4
Do. B.S., Mar.		118 5 6 1/2
Average spot price, copper, Mar.		109 10 8
Do. Electro, Mar.		118 6 11 1/2

Tin.

	£ s. d.	£ s. d.
Cash	347 15 0	348 0 0
Three months	347 0 0	347 5 0
English	334 0 0	345 0 0
Bars	346 0 0	347 0 0
Refined	—	—
Straits	—	347 0 0
Australian		347 0 0
Eastern		350 0 0
Banca		346 10 0
Official average price, cash, Mar.		369 14 5 1/2
Do. Three months, Mar.		373 7 9 1/2
Do. Settlement, Mar.		369 12 2 1/2
Average spot price, Mar.		369 9 6 1/2

Spelter.

	£ s. d	£ s. d.
Ordinary	49 0 0	—
Remelted	42 0 0	44 0 0
Hard	36 0 0	37 0 0
Electro 99.9	52 0 0	53 0 0
English	51 0 0	52 0 0
India	45 0 0	46 0 0
Zinc dust	60 0 0	65 0 0
Do. English	—	—
Zinc ashes, per cent. 70%	15 0 0	16 0 0
Official average price, Mar.		54 16 7 1/2
Average spot price, Mar.		53 9 9 1/2

Lead.

Soft foreign (net)	40 10 0
English	42 10 0
Official average price, Mar.	47 1 9 17/20
Average spot price, Mar.	46 1 2 1/2

Antimony.

	£ s. d.	£ s. d.
English regulus	72 0 0	75 0 0
Chinese		60 0 0
Crude	54 0 0	55 0 0
Ore		Nominal.

Aluminium.

Virgin Metal 98/99—. . . . 165 0 0 per ton.

Phosphor Bronze.

Ingots.	Per ton.
Alloy No. I. or II.	—
III., IV., or V.	—
IV. or VII	—
VIII.	—
XI.	—
Cast Strips and Ingots	—
Castings.	**Per lb.**
I. or II.	—
III., IV. or V.	—
IV. or VII.	—
VIII.	—
XI.	—
No. VII., Chill, Cast, Solid Cored Bars	—
Delivery 2 Cwt. free to any town.	
10 per cent. Phosphor Copper price of best selected copper.	£40 above
15 per cent. Phosphor Copper price B.S.	£50 above
Phosphor Tin (5 per cent.)	£30 above
Phosphor-bronze prices supplied by CHARLES CLIFFORD AND SON, LIMITED, FAZELEY STREET MILLS, BIRMINGHAM.	

***Chromium (Metallic).**

98/99— purity, per lb. . . . 7/6

***Nickel.**

In cubes, 98/99— purity per ton . . £230 0 0

Nickel Silver. per lb.

Ingots for raising . . . . 1/7 - 2/-
Ingots for Spoons and Forks . . 1/7 - 2/-
,, rolled to spoon size . . 1/10 - 2/3

***Tungsten Metal Powder.**

96/98— purity . . . . per lb. 3/10

***Molybdenum Metal.**

96/98— purity, per lb . . . . —

***Cobalt Metal.** £ s. d.

97— purity, per lb. . . . 0 14 0

Quicksilver.

75 lb. bottle 25 5 0

* Net, delivered Sheffield Works.

Scrap Iron and Steel.

	Cleveland. s. d.	s. d.
Steel scrap, heavy melting	—	200 0
Iron scrap cast (cupola metal)	—	200 0
(London f.o.b.).		
Heavy steel		—
Light ,,		—
Heavy cast		—

Steel Scrap.

Without Analysis—	Per ton £ s. d
Heavy steel melting scrap	10 5 0
Steel planings, turnings and borings	9 5 0
Steel planings, turnings and borings mixed with wrought-iron or other material	9 0 0
Other classes of steel scrap, whether or not mixed	9 5 0
F.o.r. or in barge at nearest siding or wharf.	
With Analysis—	
Heavy steel melting scrap not over 0.04 per cent. p. and s.	10 10 0
Heavy steel melting scrap not over 0.05 per cent. p. and s.	10 10 0

Wrought-Iron Scrap.

	£ s. d.
(1) (a) W.I. plates and sections, not less than ¼ in. thick, reasonably clear of rivets, flanged ends, etc., suitable for shearing; cable scrap and chain scrap not less than ¼ in. dia.	10 5 0
(b) Heavy W.I. scrap not less than ¼ in. thick including horseshoes, rivets and bolts, and scrap therefrom	10 5 0
(c) W.I. scrap under ¼ in. thick, and all W.I. scrap not included in classes 1, 2 and 3	10 5 0
(2) Mixed W.I. scrap	8 15 0
(3) Wrought-iron planings, turnings and borings mixed with steel or other materials	7 5 0
(4) W.I. planings, turnings and borings	7 7 6

Cast-Iron Scrap.

	£ s. d.
Heavy ord., broken, between 1½ cwt. and 10 cwt. each	10 5 0
Heavy machinery, broken between 1½ cwt. and 10 cwt. each	10 10 0
Cold blast, broken, between 1½ cwt., and 10 cwt.	12 5 0
Ingot mould, unbroken	11 10 0
Do. broken, between 5 cwt. and 2 tons each	11 15 0
Do. between 1½ cwt. and 5 cwt. each	12 0 0
Railway chairs, whole or broken for remelting	10 10 0
Heavy lumps, not exceeding 2 tons each	10 2 6
Light	9 15 0
Burnt, broken ready for cupola	9 0 0
Burnt fire bars	9 10 0
Turnings and borings, for iron and steel makers	10 0 0

Old Metal.

London—	£ s. d.
Copper (clean)	90 0 0
Brass (clean)	52 0 0
Lead (less usual draft)	31 0 0
Tea lead	29 10 0
Zinc	27 0 0
New aluminium cuttings	120 0 0
Brazier copper	80 0 0
Gunmetal	78 0 0
Hollow pewter	250 0 0
Shaped black pewter	160 0 0
(Above all d.d merchant's yard).	

Metallurgical Coke.

Durham and Northumberland—	£ s. d.
Blast furnace	2 15 6
Foundry	3 0 6
Lancs., Staffs., Yorks, Notts., Derbyshire, Lincolnshire and Midland Counties—	
Blast furnace	2 18 6
Foundry	3 10 0
F.o.t. at ovens.	